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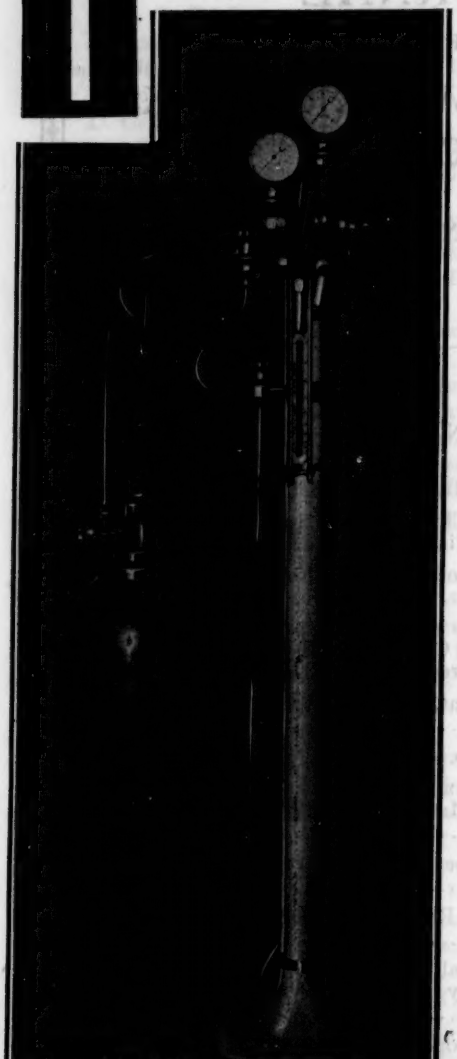

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VOL. 22 JUNE, 1930 No. 6

HYDRAULICS OF DEEP WELLS[1]

BY LELAND R. BALCH[2]

An artesian well was formerly defined as a flowing well, and to a considerable degree the general conception of today is in accordance with the original meaning of the term. Any well in which the water rises above the point at which the water bearing stratum is tapped is strictly an artesian well, the condition of a flowing well being due to the ground surface at the well being lower in elevation than the static head of water reached by the well bore. The term deep well is here used as applying to drilled wells in which the water rises above the stratum due to the hydrostatic pressure of its source. The laws of hydraulics discussed herein apply to wells so long as the lowered water surface when pumping does not fall below the elevation of the water bearing stratum.

The laws of flow into wells, the interference existing between wells in groups, the economic spacing of wells in groups, and similar questions have been discussed theoretically by several writers. Few data are available, however, which enable one to make intelligent use of the theories, or even to test the practical correctness of them.

We have a great amount of data giving the "specific capacity" of wells. This is defined simply as the capacity per foot of drawdown in the water level in a well. In the case of pumping two or more wells fairly close to each other, neither one will yield according to

[1] To be presented before the St. Louis Convention, June 5, 1930.

[2] Deceased. Formerly with Mead and Seastone, Consulting Engineers, Madison, Wis.

the specific capacity obtained from a single well owing to the mutual interference between them.

In the design and selection of pumping equipment, the submergence of the pump, the capacity and other characteristics of the equipment ought to conform as nearly as possible to the conditions which will exist.

In the problems of increasing the well water supply, either by extending the well system or by increasing the draft on the wells, the questions of proper spacing and design are seldom based on dependable information correctly used.

The following discussion is not intended to be the answer to the questions involved, but is presented as a limited amount of data bearing on the subject which may be of interest. The attempt is made to correlate the data with the theories and to devise a means by which the theories may be made of greater use and wider application than has been the case hitherto.

Mr. Chas. S. Slichter presented a comprehensive study, from the theoretical standpoint, on the movements of ground waters and the hydraulics of wells in the Nineteenth Annual Report of the United States Geological Survey, Part II. As the only concrete number to be used in applying the results to a practical case, he stated that, in the absence of available data, the radius of the circle of influence may be taken as 200 meters, this being the value used in Europe.

F. E. Turneaure[3] presents a discussion somewhat similar to Slichter's study, although less comprehensive, in which he states:

> In none of the above quantities is there anything that involves the amount of water actually flowing in the ground. . . . . The effect of this element is all included in the values of R, the radius of the circle of influence and it is in the determination of this that the chief difficulty arises.

He further points out that since this term of the equation appeared in the form $\frac{1}{\log \frac{R}{r}}$ a large variation in "R" affects the calculation of flow for a single well but slightly.

Briefly summarized, the equations resulting from the investigations of and presented by Chas. S. Slichter are given in the following:

Nomenclature (see figure 1)

f = flux or yield of well in cubic feet per minute.
Q = yield of well in gallons per minute.

[3] Public Water Supplies, Turneaure and Russell, Third Edition, p. 258.

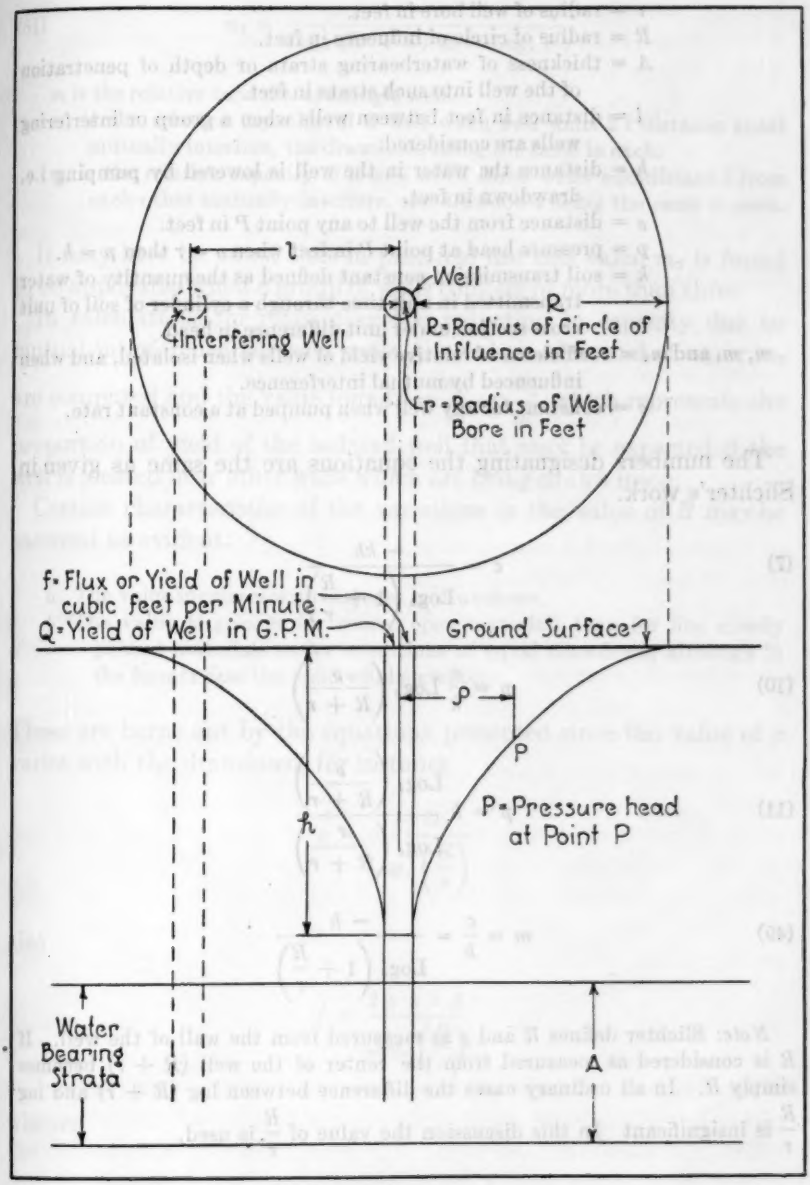
l
Well
R
Interfering Well
R=Radius of Circle of Influence in Feet
r=Radius of Well Bore in Feet
f=Flux or Yield of Well in cubic feet per Minute.
Q=Yield of Well in G.P.M.
Ground Surface
s
P
P=Pressure head at Point P
h
Water Bearing Strata
A

FIG. 1

r = radius of well bore in feet.
R = radius of circle of influence in feet.
A = thickness of waterbearing strata or depth of penetration of the well into such strata in feet.
l = distance in feet between wells when a group or interfering wells are considered.
h = distance the water in the well is lowered by pumping i.e. drawdown in feet.
ρ = distance from the well to any point P in feet.
p = pressure head at point P in feet when $\rho = r$ then $p = h$.
k = soil transmission constant defined as the quantity of water transmitted in unit time through a cylinder of soil of unit cross section under unit difference in head.
m, m_1 and m_2 = coefficients of relative yield of wells when isolated, and when influenced by mutual interference.
c = constant for any well when pumped at a constant rate.

The numbers designating the equations are the same as given in Slichter's work.

(7) $$c = \frac{-kh}{\text{Log}_e\left(1 + \frac{R}{r}\right)}$$

(10) $$p = \frac{c}{k}\,\text{Log}_e\left(\frac{\rho}{R + r}\right)$$

(11) $$p = h\,\frac{\text{Log}_e\left(\frac{\rho}{R + r}\right)}{\text{Log}_e\left(\frac{r}{R + r}\right)}$$

(49) $$m = \frac{c}{k} = \frac{-h}{\text{Log}_e\left(1 + \frac{R}{r}\right)}$$

Note: Slichter defines R and ρ as measured from the wall of the well. If R is considered as measured from the center of the well $(R + r)$ becomes simply R. In all ordinary cases the difference between log $(R + r)$ and log $\frac{R}{r}$ is insignificant In this discussion the value of $\frac{R}{r}$ is used.

(42) $$m_1 = \frac{2h}{\text{Log}_e\,(4\,lr^3 + \cdot 4\,l^2r^2) - \text{Log}_e\,R^2\,(2\,l + R)^2}$$

$$(54) \qquad m_2 = \frac{-h}{\text{Log}_e\,(R^2 + l^2)\,R - \text{Log}_e\,l^2\,r}$$

m is the relative capacity of a single well.

m_1 is the relative capacity of a well when two wells $2\,l$ distance apart mutually interfere, the drawdown being the same in each.

m_2 is the relative capacity of a well when three wells equidistant l from each other mutually interfere, the drawdown being the same in each.

It may here be noted that in practical use this value m_2 is found to be applicable when a group of wells consists of more than three.

In calculations for estimating the reduction in capacity due to mutual interference between wells, the values of m and of m_1 or m_2 are computed and the value found for $\frac{m_1}{m}$ or $\frac{m_2}{m}$, which represents the proportion of yield of the isolated well that may be expected if the well is located near other wells which are being drawn upon.

Certain characteristics of the variations in the value of R may be assumed as evident:

a. The value increases with increase in drawdown.

b. The value is greater for coarse open materials than for fine closely packed materials under conditions of equal drawdown, although in the former case the yield will be greater.

These are borne out by the equations presented since the value of c varies with the drawdown, for instance

$$c = \frac{-kh}{\text{Log}_e\left(\frac{R}{r}\right)}$$

also

$$f = \frac{2\,\pi\,h\,k\,A}{\text{Log}_e\left(\frac{R}{r}\right)}$$

whence

$$f = 2\,\pi\,A\,c \text{ or } c = \frac{f}{2\,\pi\,A}$$

For any particular well $2\pi A$ is constant and hence c varies directly with f, which in turn, for all ordinary rates of pumping, varies directly with the drawdown h.

From the equation (7)

$$\log_e\left(\frac{R}{r}\right) = \frac{Kh}{c}$$

in which K is the transmission constant whose value depends upon the coarseness of the waterbearing stratum. The value of $\log_e\left(\frac{R}{r}\right)$ is thus seen to vary directly with the value of K and directly with the ratio $\frac{h}{c}$ which values are mutually inter-dependent.

While it is necessary for reasonably satisfactory results that the values of R be only roughly approximate, there are practically no published data, so far as the writer is aware, which may be used as a guide to judgment in making the assumption of values.

Slichter bases his examples on using R as 200 meters, roughly 600 feet, as used in European practice.

In Slichter's equation (11) we have the means of calculating the value of R, provided we have observations on the water level within the circle of influence.

(11)
$$\frac{p}{h} = \frac{\text{Log}_e \frac{\rho}{R}}{\text{Log}_e \frac{r}{R}}$$

$$\frac{p}{h} \times \text{Log}_e \frac{r}{R} = \text{Log}_e \frac{\rho}{R}$$

and

$$r^{\frac{p}{h}} \times R^{1-\frac{p}{h}} = \rho$$

In equation (49), (42) and (54), we have the means of calculating the value of R, if we have observations giving the yield of a well without interference and again with interference at the same drawdown below static level. These values are relatively the same as m and m_1 or m_2, as the case may be. Their ratio then equals $\frac{m_1}{m}$ or $\frac{m_2}{m}$.

$$\frac{m_1}{m} = \frac{\dfrac{2\,h}{\text{Log}_e\,(4\,lr^3 + 4\,l^2r^2) - \text{Log}_e\,R^2\,(2\,l + R)^2}}{\dfrac{-\,h}{\text{Log}_e\,\dfrac{R}{r}}}$$

$$\frac{m_1}{m} \times \text{Log}\,(4\,lr^3 + 4\,l^2r^2) = \frac{m_1}{m}\,\text{Log}\,R^2\,(2\,l + R)^2 - 2\,\text{Log}\,\frac{R}{r} \tag{55}$$

$$\frac{m_2}{m} = \frac{\dfrac{-\,h}{\text{Log}_e\,(R^2 + l^2)\,R - \text{Log}_e\,l^2r}}{\dfrac{-\,h}{\text{Log}_e\,\dfrac{R}{r}}} = \frac{\text{Log}_e\,\dfrac{R}{r}}{\text{Log}_e\,(R^2 + l^2)\,R - \text{Log}_e\,l^2r}$$

$$\frac{m_2}{m} \times \text{Log}\,l^2r = \frac{m_2}{m}\,\text{Log}\,(R^2 + l^2)\,R - \text{Log}\,\frac{R}{r} \tag{56}$$

In the above expressions (55) and (56), the lefthand member becomes finite, R is the only unknown, and they can be approximately solved by the method of trial and error if values are assigned to R and the results plotted on coördinate paper.

ROCKFORD DATA

During the studies made prior to the reconstruction of the water works at Rockford, Illinois, information along this line was obtained.

At the old water works, the centrifugal pumps were located at the bottom of a shaft, from which tunnels extended carrying suction pipes which were connected into the well casings at a considerable distance below ground surface. In addition to the group of wells being pumped by the centrifugals, there were three wells extending into the Potsdam sandstone which were not being pumped. These are known as the Peach Street wells. The elevation of water level in these wells was taken while the shaft and tunnel system was in operation, thus affording three direct observations on the elevation of water level within the circle of influence.

In addition to this, the existence of two deep wells a considerable distance from the station and which were pumped only occasionally afforded the means of observing the static head of the water in the Potsdam formation at Rockford. Pumping tests of these wells furnished data as to the specific capacity of an isolated well with no interference.

The water level in the Peach Street wells had been observed in 1910, and the measurements made in 1919 showed substantially the same conditions, within the limits of error in making the former, which were made by dropping a wooden float on a cord down the well casing. The results of the observations are given in table 1.

TABLE 1

Water surface elevations (city datum) in deep wells at Rockford, Ill.

YEAR	STATIC LEVEL, MEASURED AT OUTLYING WELL NO. 8	SHAFT SYSTEM	PEACH STREET WELLS		
			No. 2	No. 3	No. 5
1910	———	21.5	74.2	82.5	91.0
1919	104.25	25.0	74.5	82.5	92.0
Distance from shaft system.....6,000 ft.		0	164 ft.	390 ft.	1,055 ft.

TABLE 2

DISTANCE FROM PUMPING STATION	DISTANCE FROM LOWEST WELL WHICH IS 2,000 FEET FROM STATION	OBSERVED ELEVATIONS OF WATER	
		1898	1902
feet	*feet*	*feet*	*feet*
2,000	0	170	170
3,000	1,000	206	
3,500	1,500	207	
4,000	2,000		197
8,100	6,100	214	
10,400	8,400	213	209
16,000	14,000	217.5	212
17,300	15,300	218.5	209.5
19,000	17,000		217
Original water surface		225	

MEMPHIS DATA

Public Water Supplies, by Turneaure and Russell, presents a diagram of ground water curves observed at Memphis, Tennessee, taken from the *Engineering Record*, Vol. XLVI, page 513.

Lacking the exact observations the points were read from the diagram and are as given in table 2.

These wells are only about 350 feet deep, into a sand stratum which lies below a clay stratum. The water rises essentially to the surface of the ground in the well casings which have 50-foot brass strainers.

A single well produced 700 g.p.m. at 30-foot drawdown, while eight wells produced about 1750 g.p.m. at the same head.

Sufficient data for calculating the relative flow under conditions of interference are not available.

MADISON DATA

In the Madison group well system we have the case of the Patterson Street well producing 1027 g.p.m. at 71-foot drawdown when no surrounding wells were operated, and 920 g.p.m. at 75-feet drawdown when the Main Street well, 250 feet distant, was being pumped at essentially the same draft: 1027 g.p.m. at 71-foot head should by proportion yield 1085 g.p.m. at 75-foot head. The ratio of relative yields with and without interference

$$\frac{m_1}{m} = \frac{920}{1085} = 0.848$$

HARVARD, ILLINOIS, DATA

At the Harvard Water Works there are two 8-inch deep wells 27 feet apart within the pump house. These were pumped by means of deep well reciprocating plunger pumps. Well No. 1 produced 88 g.p.m. at 35.5-foot drawdown. When No. 2 was operated at 110 g.p.m. the water level in No. 1 dropped 14.5 feet to produce 88 g.p.m. The drawdown in No. 2 when pumping was not measured because the well pumping equipment was such that the pump head had to be removed to sound the well.

The data for different rates of pumping are manifestly not strictly comparable since the drawdown in each well is not the same owing to the different capacities of the pumps.

Information regarding the thickness of water-bearing strata could not be obtained.

The data shown on Rockford, Madison and Harvard wells constitute all of the first-hand information bearing on this subject. The Memphis data were taken from the article published in the *Engineering Record.*

CALCULATION OF WELL CHARACTERISTICS

The Rockford data, arranged for calculation, are given in table 3.

The drawdown surface elevation shown in table 1 was measured by a vacuum gage. The head on the well is less than this by the fric-

tion of flow up the well bore and piping. An estimate of the friction head was made according to the best information available and was taken as 0.95 foot per 100 feet of well applied as acting for one-half the length of well bore. The value used in the computation was 5.75 feet making the value of $h = 77.0$ feet, instead of 82.75 as would be obtained if no account were taken of this influence.

The values shown in table 3 were substituted in the expression:

$$\frac{p}{h} \text{ Log } r + \left(1 - \frac{p}{h}\right) \text{ Log } R = \text{ Log } \rho$$

TABLE 3

OBSERVATION NO.	WELL NO.	h	ρ	p	$\frac{p}{h}$	$1 - \frac{p}{h}$	$\log \rho$
1	Shaft	77.0	0	77.0	1.0	0	
2	2		164	29.75	0.386	0.614	2.2148
3	3		390	21.75	0.282	0.718	2.5911
4	5		1,055	12.25	0.159	0.841	3.0233

The data furnish supposedly simultaneous values within this limit of accuracy, and the analytical solution was possible by combining the resulting equations.

Combining 2 and 3, $R = 4157$
2 and 4, $R = 3900$
3 and 4, $R = 3810$
Average value $R = 3956$

The variations from the mean being +5 percent and −3.7 percent. The value of

$$m = \frac{c}{k} = \frac{p}{\text{Log}_e \frac{\rho}{R}}$$

was then calculated, using the value of

$R = 4000$ feet, resulting in
$m = 9.27$ as the average value at the rate of pumping, then existing.

Comparison of the calculated and observed points on the pressure curve are shown in figure 2.

Well No. 8 at Rockford, some 6000 feet from the shaft system, is equipped with a deep well centrifugal pump with a meter in the discharge pipe. During a test run, this well yielded 1600 g.p.m. at a drawdown below static level (elevation 104.25 city datum) of 85.7 feet. The depth of the well is 1500 feet cased with 450 feet of

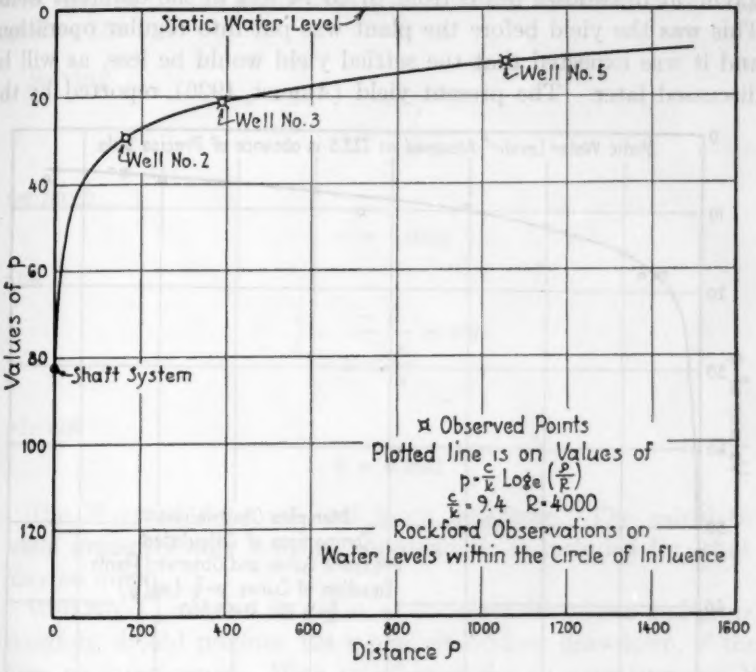

FIG. 2

drive pipe. The well bore in the Potsdam formation is 12 inches and

$$A = 1050 \text{ feet}$$

$$c = \frac{f}{2\pi A} = 0.0323 \text{ at 85.7 foot drawdown}$$

and proportionately $c = 0.0291$ at 77-foot head; from the calculations on wells 2, 3, and 5, we have $m = \frac{c}{k}\, 9.27$ whence $k = 0.00314$.

Owing to the close consistency observed between the specific

capacities of well No. 8 and the new station wells located nearly a mile from the shaft system and on the opposite side, the use of the value $\frac{c}{k}$ obtained from the shaft system data is believed to be justified.

A test run of the four new wells pumped by air lift produced 5236 g.p.m. at drawdown heads from 67 to 74 feet in the different wells. This was the yield before the plant was put into regular operation, and it was expected that the settled yield would be less, as will be discussed later. The present yield (August, 1926), reported by the

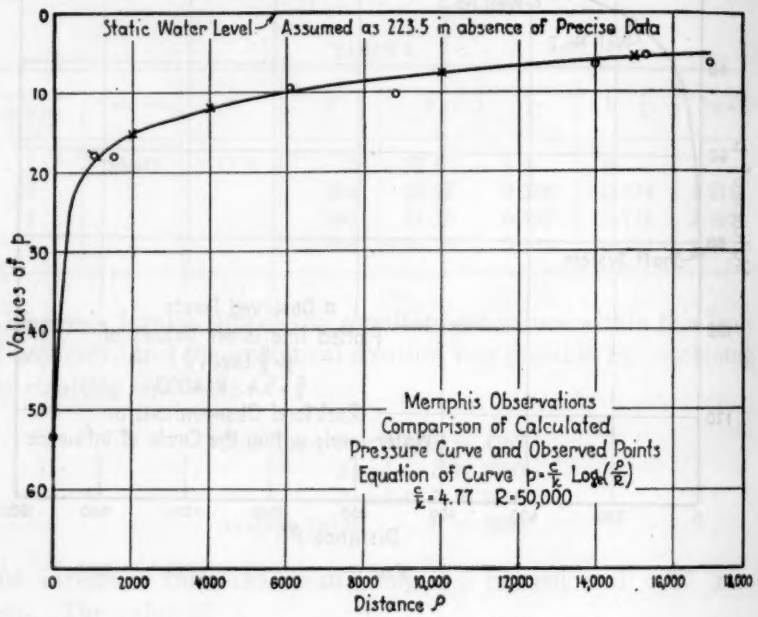

FIG. 3

plant chief, is 5.75 million gallons per 24 hours at an average drawdown of 79 feet.

The data on the Memphis wells are manifestly indefinite. The pressure curve based on these data was calculated similarly to that for the Rockford well, and is shown in figure 3, together with the observations as scaled from the published diagram. The results indicate that under the given conditions the value of R was about 50,000 feet and the value of $m = \frac{c}{k}$ was about 4.77.

The information on the Madison well is very limited, being one observation each of yield under conditions of isolation and interference, giving the single value $\frac{m_1}{m} = 0.848$. This was substituted in the combined equations Nos. 49 and 42, and the approximate solution was reached by the methods of trial and error resulting in the value of $R = 850$ feet.

Solving

$$c = \frac{f}{2 \pi A}$$

we have

$$c = 0.0364$$

and

$$\frac{c}{k} = \frac{-h}{\text{Log}_e \frac{R}{r}} = 8.91$$

whence

$$k = 0.0041$$

The Harvard data are still more indefinite. The calculation, while evidently only roughly approximate, is included for what it may be worth.

Well No. 1 produced 88 g.p.m. at 35.5-foot drawdown and proportionately should produce 124 g.p.m. at 50-foot drawdown, if there were no interference. With interference due to operating well No. 2, it yielded 88 g.p.m. at 50-foot drawdown, then

$$\frac{m_1}{m} = \frac{88}{124} = 0.71 \qquad 2l = 27 \text{ feet} \qquad r = 333 \text{ feet}$$

Substituting these values in equations Nos. 49 and 42 as before and solving by trial and error, the value of $R = 550$ feet, is obtained:

$$c = \frac{f}{2 \pi A} = \frac{88}{7.48 \times 6.28 \times 1200} = 0.00156$$

$$\frac{c}{k} = \frac{-h}{\text{Log}_e \frac{R}{r}} = \frac{-88}{7.41} = 11.86$$

whence

$$k = \frac{0.00156}{11.86} = 0.0001315$$

CALCULATION OF INTERFERENCE

The preceding matter and discussion give the bases which have been used in calculating interference between wells and estimating the interference which would result when locating sites for new wells. An example of the use of the equations (as used) in estimating the aggregate yield of the wells drilled for Rockford water works in 1922 will be given.

From the data obtained on the water bearing strata given as Rockford Data herein, the calculated value of $m = 8.5$ when $h = 80$, and the value of R as 4000 feet as applying to an isolated well. For a group of four 12-inch wells averaging about 400 feet apart, which was the condition at the new plant, and for a drawdown of 80 feet, we have

$$m_2 = \frac{h}{\log_e (R^2 + l^2)\, R - \log_e l^2 r} = \frac{80}{25.31 - 11.3} = 5.72$$

The relative yield is then $\frac{5.72}{8.5} = 67.2$ per cent. That is, each well pumped to 80 feet below static level will furnish about 67.2 per cent of the amount it would supply, if isolated.

From a test of well No. 8 it was expected that the yield at 80-foot head should be 1490 g.p.m. (proportional to 1600 at 85.7 feet) if isolated or 1000 g.p.m. in the group from the foregoing calculation. Four wells would then furnish 4000 g.p.m. or at the rate of about 5.75 million gallons per day at 80-foot draft.

These wells actually produced on test when first put into service at the rate of 7.5 million gallons per day at drawdowns varying from 70 to 75 feet in the different wells. After considerable period of use, however, we were informed that the yield is not so great as at first. Test data on the settled yield are not available, but the operator states that the four wells yield somewhat less than 6 million gallons at 79 foot drawdown.

Table 4 gives the values of $\frac{1}{\log R/r}$ calculated, for various values of R and sizes of well for use in making calculations.

TABLE 4

$$\frac{c}{K} = \frac{h}{\text{Log}_e\left(\frac{R}{r}\right)} \text{ or } \frac{f}{h} = \frac{2\pi Ak}{\text{Log}_e\left(\frac{R}{r}\right)} \text{ or } \frac{f}{h2\pi Ak} = \frac{1}{\text{Log}_e\left(\frac{R}{r}\right)}$$

Note: $A = \frac{R}{r}$, $B = \log_{10}\frac{R}{r}$, $C = \frac{1}{\log_e \frac{R}{r}}$, in table below.

R		VALUES OF $\frac{1}{\text{Log}_e\left(\frac{R}{r}\right)}$						
		Diameter of well						
		4 inches	6 inches	8 inches	10 inches	12 inches	15 inches	18 inches
		0.33 feet	0.50 feet	0.67 feet	0.83 feet	1.00 feet	1.25 feet	1.50 feet
500	A	3,000	2,000	1,500	1,200	1,000	800	667
	B	3.477	3.301	3.176	3.079	3.000	2.903	2.824
	C	0.125	0.131	0.137	0.141	0.145	0.150	0.154
1,000	A	6,000	4,000	3,000	2,400	2,000	1,600	1,335
	B	3.778	3.602	3.477	3.380	3.301	3.204	3.125
	C	0.115	0.120	0.125	0.128	0.131	0.135	0.139
1,500	A	9,000	6,000	4,500	3,600	3,000	2,400	2,000
	B	3.954	3.778	3.653	3.556	3.477	3.380	3.301
	C	0.110	0.115	0.119	0.122	0.125	0.128	0.131
2,000	A	12,000	8,000	6,000	4,800	4,000	3,200	2,670
	B	4.079	3.903	3.778	3.681	3.602	3.505	3.426
	C	0.106	0.111	0.115	0.118	0.120	0.124	0.127
3,000	A	18,000	12,000	9,000	7,200	6,000	4,800	4,000
	B	4.255	4.079	3.954	3.857	3.778	3.681	3.602
	C	0.102	0.106	0.110	0.113	0.115	0.118	0.120
4,000	A	24,000	16,000	12,000	9,600	8,000	6,400	5,330
	B	4.3802	4.204	4.079	3.982	3.903	3.806	3.727
	C	0.099	0.103	0.106	0.109	0.111	0.114	0.116
5,000	A	30,000	20,000	15,000	12,000	10,000	8,000	6,670
	B	4.477	4.301	4.176	4.079	4.000	3.903	3.824
	C	0.097	0.101	0.104	0.106	0.109	0.111	0.114
7,500	A	45,000	30,000	22,500	18,000	15,000	12,000	10,000
	B	4.653	4.477	4.352	4.255	4.176	4.079	4.000
	C	0.0935	0.097	0.100	0.1025	0.104	0.106	0.109

TABLE 4—*Concluded*

R		VALUES OF $\frac{1}{\text{Log}_e\left(\frac{R}{r}\right)}$						
		Diameter of well						
		4 inches	6 inches	8 inches	10 inches	12 inches	15 inches	18 inches
		0.33 feet	0.50 feet	0.67 feet	0.83 feet	1.00 feet	1.25 feet	1.50 feet
10,000	A	60,000	40,000	30,000	24,000	20,000	16,000	13,350
	B	4.778	4.602	4.477	4.380	4.3010	4.204	4.124
	C	0.091	0.0945	0.097	0.099	0.101	0.103	0.105
20,000	A	120,000	80,000	60,000	48,000	40,000	32,000	26,700
	B	5.079	4.903	4.778	4.681	4.602	4.505	4.426
	C	0.0855	0.0887	0.091	0.0928	0.0945	0.0965	0.098
40,000	A	240,000	160,000	120,000	96,000	80,000	64,000	53,500
	B	5.380	5.204	5.079	4.982	4.903	4.806	4.728
	C	0.0805	0.0835	0.0855	0.087	0.0887	0.0905	0.0920
50,000	A	300,000	200,000	150,000	120,000	100,000	80,000	66,700
	B	5.477	5.301	5.176	5.079	5.000	4.903	4.824
	C	0.0795	0.0820	0.0838	0.0855	0.087	0.0885	0.090

Interference

The expressions for the flow of a well as represented by "m" are for isolated well

$$m = \frac{h}{\log_e (R/r)}$$

For one of a group of three wells.

$$m_2 = \frac{h}{\log_e (R^2 + l^2)\, R^2 + \log_e l^2 r}$$

The relative flow of a well in a group as compared with an isolated well of the same characteristics is

$$I = \frac{m_2}{m}$$

and is equal to

$$\frac{\text{Log}_e \left(\frac{R}{r}\right)}{\text{Log}_e (R^2 + l^2)\, R + \text{Log}_e l^2 r}$$

TABLE 5

Values of I for various values of l and R

l	$\text{Log}_e l^2 r$	$R = 1{,}000$ $\text{Log}_e \frac{R}{r} = 7.60$		$R = 2{,}000$ $\text{Log}_e \frac{R}{r} = 8.795$		$R = 4{,}000$ $\text{Log}_e \frac{R}{r} = 9.05$		$R = 6{,}000$ $\text{Log}_e \frac{R}{r} = 9.390$		$R = 10{,}000$ $\text{Log}_e \frac{R}{r} = 9.91$		$R = 50{,}000$ $\text{Log}_e \frac{R}{r} = 11.51$	
		Log_e*	I	Log_e*	I	Log_e*	I	Log_e*	I	Log_e*	I	Log_e*	I
100	8.52	12.21	0.622	14.27	0.577	16.43	0.550	17.56	0.535	19.08	0.520	23.93	0.482
200	9.91	10.87	0.699	12.89	0.647	15.06	0.600	16.18	0.580	17.69	0.560	22.54	0.511
400	11.28	9.59	0.792	11.55	0.713	13.70	0.660	14.81	0.634	16.34	0.607	21.17	0.545
600	12.08	8.94	0.850	10.80	0.762	12.91	0.700	14.01	0.670	15.54	0.637	20.37	0.565
800	12.67	8.54	0.890	10.27	0.802	12.35	0.73	13.43	0.700	14.96	0.662	19.78	0.583
1,000	13.11	8.31	0.914	9.91	0.831	11.93	0.756	13.01	0.722	14.53	0.682	19.35	0.595
1,500	13.93	7.95	0.955	9.30	0.886	11.16	0.808	12.21	0.769	13.72	0.722	18.54	0.621
2,000	14.51	7.81	0.973	9.06	0.909	10.67	0.845	11.69	0.803	13.15	0.753	17.97	0.641
3,000	15.29	7.73	0.984	8.68	0.949	10.11	0.890	11.01	0.853				
4,000	15.89	7.66	0.992	8.54	0.964	9.74	0.925	10.57	0.889	11.89	0.833	16.60	0.695
6,000	16.70			8.46	0.974	9.48	0.950	10.05	0.934	11.21	0.883	15.80	0.730
8,000	17.27			8.33	0.989	9.26	0.975	9.83	0.955	10.84	0.914	15.23	0.756
10,000	17.73					9.15	0.990	9.69	0.969	10.60	0.935	14.79	0.780
15,000	18.54							9.54	0.985	10.43	0.955	14.02	0.822
20,000	19.80											12.82	0.900

* $\text{Log}_e (R^2 - l^2)R - \text{Log}_e l^2 r$.

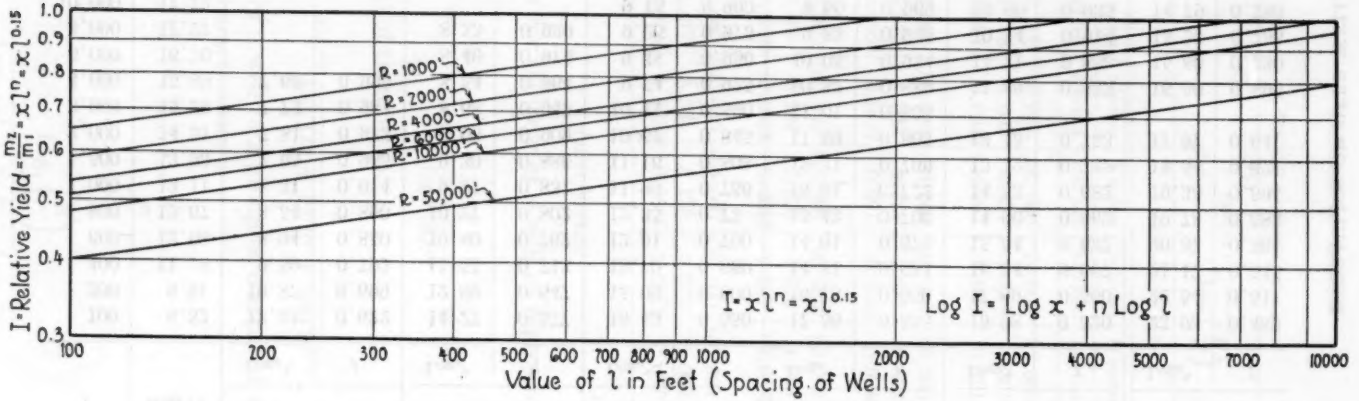
I = Relative Yield = m2/m1 = x l^n = x l^0.15
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
R = 1000'
R = 2000'
R = 4000'
R = 6000'
R = 10000'
R = 50,000'
I = x l^n = x l^0.15
Log I = Log x + n Log l
100
200
300
400
500
600
700
800
900
1000
2000
3000
4000
5000
7000
10000
Value of l in Feet (Spacing of Wells)

FIG. 4

Values of I were computed for various values of l, and R (see table 5) and plotted on logarithmic paper as shown in figure 4. The log plotting of values I and l give a series curve, essentially parallel, having the form

$$\log I = \log x + n \log l \text{ or } I = xl^n$$

in which the approximate value of n was 0.15. Each curve had an individual value of x depending upon the value of R. Log plotting each value of x against its respective R, see figure 5,

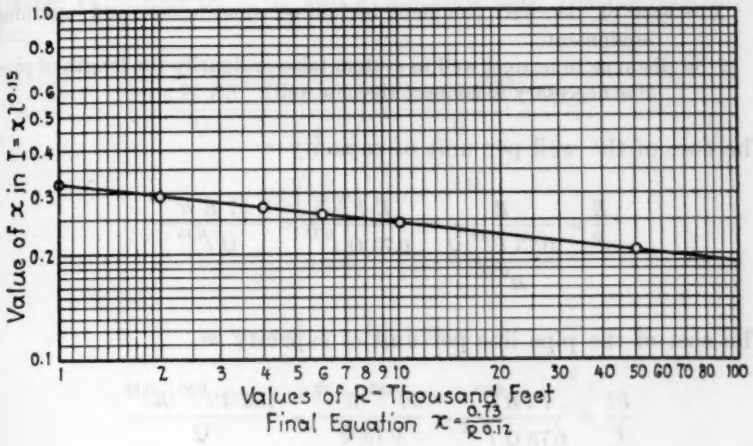

FIG. 5

produced a line having the form $\log x = \log y - z \log R$ or $x = \frac{y}{R^z}$ in which the value of z is 0.12.

The final empirical equation for the variation in yield under conditions of mutual interference for different values of R and l is

$$I = \frac{0.73\ l^{0.15}}{R^{0.12}}$$

ECONOMIC SPACING OF WELLS

A question of importance is found in the problems relating to extension of deep well supplies. Various minimum distances for well spacing have been stated, and doubtless every one who has been called upon to decide the question has had a variety of answers depending upon experience, judgment, advice and guessing facilities.

Consideration of this question brought the problem down to the single statement:

When the spacing is such that the cost of the necessary connecting pipe lines reaches the point where an additional length makes the cost more than the value of the additional water secured, the economical limit of well spacing is reached.

Let P = unit cost (per foot) of pipe lines necessary to connect the well into the water system.
Q = normal yield of an isolated well.
F = IQ = yield of well under conditions of inteference.
E = cost of the well complete including construction and pumping equipment.
l = distance to nearest well in system (also ordinarily the length of pipe line necessary to connect the new well).

The cost of the well per unit of capacity =

$$\frac{E}{F} = \frac{E}{\frac{0.73\, l^{0.15}\, Q}{R^{0.12}}} = \frac{E\, R^{0.12}}{0.73\, Q\, l^{0.15}} = \frac{1.37\, E\, R^{0.12}}{Q\, l^{0.15}}$$

The cost of the pipe line per unit of capacity =

$$\frac{Pl}{F} = \frac{Pl\, R^{0.12}}{0.73\, Q\, l^{0.15}} = \frac{Pl^{0.85}\, R^{0.12}}{0.73\, Q} = \frac{1.37\, Pl^{0.85}\, R^{0.12}}{Q}$$

$\frac{E}{F}$ is the cost of the water supply per unit of capacity. The greater the spacing the greater the value of F due to lessened interference, and the smaller the unit cost, E being a constant.

$-d\frac{E}{F}$ represents the decreasing rate of change in the cost per unit of capacity due to this variation, that is, it represents the cost of the additional water supply secured by virtue of increased capacity.

$\frac{Pl}{F}$ represents the cost of pipe lines per unit of capacity, which also reduced with increase in F due to lessened interference, but also increases with increased spacing a.

$d\frac{Pl}{F}$ represents the rate of change in pipe line cost per unit of capacity; that is, it represents the cost of additional length of pipe lines by virtue of increasing the spacing a.

From the statement of the proposition: when

$$d\left(\frac{Pl}{F}\right) = -\,d\left(\frac{E}{F}\right)$$

the economical spacing is had. Then

$$-\,d\left(\frac{1.37\,ER^{0.12}}{Ql^{0.15}}\right) = +\,d\left(\frac{1.37\,Pl^{0.85}\,R^{0.12}}{Q}\right)$$

In these equations Q, E, R and P are constants, l is the variable. Then

$$\frac{-\,1.37\,ER^{0.12}}{Q}\,d\left(\frac{1}{l^{0.15}}\right) = \frac{1.37\,PR^{0.12}}{Q}\,d\,(l^{0.85})$$

$$-\,Ed\left(\frac{1}{l^{0.15}}\right) = Pd\,(l^{0.85})$$

$$-\,Ed\,(l^{-\,0.15}) = Pd\,(l^{0.85})$$

$$dx^n = nx^{n-1}\,dx$$

$$-\,(E)\,(-\,0.15\,l^{-\,1.15}) = P\,0.85\,l^{-\,0.15} = \frac{0.85\,P}{l^{0.15}}$$

$$+\,0.15\,El^{-\,1.15} = 0.85\,Pl^{-\,0.15}$$

$$\frac{l^{-\,1.15}}{l^{-\,0.15}} = \frac{0\,85\,P}{+\,0.15\,E}$$

$$l^{-1} = \frac{+\,17\,P}{3\,E}$$

or

$$\frac{1}{l} = \frac{17\,P}{3\,E}$$

$$l = \frac{3\,E}{17\,P}$$

or

$$Pl = \frac{3}{17} E$$

That is, the economical spacing is obtained when the cost of connecting the well into the system is equal to three-seventeenths of the cost of the well complete with its pumping equipment.

CONCLUSIONS

The matters discussed in this paper are not considered as conclusive because of the limited data available for comparison. The results are set forth for what they may be worth, and constitute the information along this line which has come to the knowledge of the writer. It should be stated that the equations, methods of calculation, etc., as shown have proved themselves of very great value in problems relating to well supplies. In general, the results obtained in predicting yield of wells have been sufficiently close to the estimates made by these methods to warrant their use.

The predictions of well capacities under conditions of mutual interference at Rockford, Illinois, and Dubuque, Iowa were made along the lines discussed and the results attained were extremely gratifying.

The discussion regarding the economic spacing of wells is original with the writer. It is the first attempt to attack the problem in this manner that has come to his attention.

SELECTION OF EQUIPMENT FOR CLOVE PUMPING STATION, STATEN ISLAND SYSTEM[1]

By William Flannery[2]

The Clove Pumping Station is located on Victory Boulevard and Ontario Avenue about three quarters of a mile south of the Silver Lake Reservoir in the Borough of Richmond. It serves a district at the northerly end of Staten Island, comprising a high pressure area of some 7 square miles and an intermediate pressure zone of more than 4 miles in extent. Within the limits of this territory, the elevation of which places it beyond the reach of service from the main reservoir at Silver Lake, are several of the most desirable and more highly developed residential neighborhoods of the borough.

The original steam driven station, which was located adjacent to the present one was built in 1886 and operated by a private company in conjunction with the development of driven wells up to 1902, at which time it was taken over by the city.

In 1923, it was decided, rather than replace or enlarge the wells, the yield from which had been steadily falling off, to convert the station into a booster connecting the suction to the Catskill service, which was available at 30 pounds per square inch.

Shortly thereafter, it was agreed that repairs or replacements either of the frame structures that housed the station equipment, or of the equipment itself which was composed mainly of units that had already given their best service at some other station before being transferred to Clove, would not be practicable.

The new station, which was to occupy a site adjacent to the old one, would be called upon to provide the following service, drawing its supply from a 24-inch main in which water from Silver Lake Reservoir at 30 to 35 pounds per square inch was available.

THE HIGH PRESSURE ZONE

A quantity of water, averaging 3.5 to 4 m.g.d., was needed at a pressure of approximately 135 pounds pressure per square inch,

[1] Presented before the Toronto Convention, June 25, 1929.

[2] Mechanical Engineer, Department of Water Supply, Gas and Electricity, New York, N. Y.

ranging in delivery rates throughout the day from 2.5 to 5 m.g.d. The variation in the draft is of particular moment since the standpipe on the high pressure system cannot be expected to carry the service unaided for more than an hour at the 3 m.g.d. rate.

THE INTERMEDIATE ZONE

An average of 350,000 g.p.d. was needed at a pressure of 55 pounds per square inch. The capacity of the intermediate district reservoir being 2.5 m.g. renders the time and date of pumping to replenish it subject, to a great degree, to the choice and convenience of the operating force.

In comparing the different types of equipment from which a selection was to be made it was assumed that the station would have three pumping units for the high service and one for the intermediate. Each of the pumps would have a capacity of 3 m.g.d. One of the high service pumps was to be considered as a spare. No reserve pumping unit was provided for the intermediate service since this could be taken care of in emergency by bleeding from the high.

Four types of drive were considered, viz., electric, motors, steam turbines, gas engines and Diesel oil engines. The comparative costs of several types are shown in table 1.

The figures in table 1, which were computed in 1923 before it had been determined to abandon the wells and convert the station to a booster, were based upon a driven well installation having a total head of 313 feet on the high service and 134 feet on the intermediate. It was assumed that the station would deliver six millions on the high and three millions on the intermediate for 365 days in the year.

The high operating cost for the electric driven station was due to the inability of the department at that time to procure a better rate than 5 cents per kilowatt hour from the light and power company serving the borough.

In August, 1925, bids were taken on a Diesel driven station of four pumping units designed for booster service. Before the award was made, however, the Staten Island Edison Corporation which had taken over the properties and franchise of the Richmond Light and Power Company, and was engaged in a vigorous campaign for additional power load, offered to serve the City with current on the basis of $75.00 per year per horsepower of demand. This rate has worked out in practice to an average of 1.27 cents per kilowatt hour. It is interesting to note that, if we substitute this rate for the 5 cent rate

in the figures previously made for the electric station, it alters the costs to read as follows:

Total operating cost	$71,314
Cost per million foot gallons	0.085693
Cost per million gallons	$21.72

TABLE 1

Comparative costs of motive power

TYPE OF EQUIPMENT	MOTOR DRIVEN	STEAM TURBINES	GAS ENGINES	OIL ENGINES
Ground and buildings	$40,580	$93,916	$110,845	$71,670
Equipment	34,549	128,087	138,460	132,465
Total first cost	75,129	222,003	249,305	204,135
Fixed charges (15 percent of first cost)	11,269	33,300	37,395	30,620
Fuel or current	187,000	36,200	19,500	28,600
Labor	9,264	24,318	24,318	16,792
Lubricants	525	600	1,697	1,932
Miscellaneous	880	2,300	2,300	1,590
Maintenance and repairs, 2.5 percent	1,878	5,550	6,233	5,103
Operating charges	199,547	68,968	54,048	54,017
Total operating costs: viz., operating charges plus fixed charges	210,816	102,268	91,443	84,637
Million foot gallons	832,200	832,200	832,200	832,200
Million gallons	3,285	3,285	3,285	3,285
Cost per million foot gallons	$0.25332	$0.122888	$0.109881	$0.101702
Cost per million gallons, dollars	64.18	31.13	27.84	25.76

Round figures, in dollars

	ELECTRIC	STEAM	PRODUCER GAS	OIL
Total investment	75,000	222,000	249,000	204,000
Total annual cost, fixed and operating charges	211,000	102,000	91,000	85,000
Cost per million gallons	64	31	28	26

With this rate in view the plans for both buildings and equipment were redrawn and work on a contract for an electric driven station was started in May, 1927. The station went into service in August, 1928.

The equipment as at present installed and operating is as follows.

Three high service centrifugal motor driven units designed for a total lift of 254 feet: The pumps are of the 2-stage type of 3 m.g.d. capacity each, direct connected to a 200 h.p., 440 volt, 60 cycle, 3 phase, slip ring motor. The normal full load speed of each motor is 1165 r.p.m.

One intermediate service pump designed for 70 feet lift and 3 m.g.d. capacity, driven by a 60 H.P. motor of type similar to the above: This pumping unit is made up of two separate pumps mounted on the same shaft, operating in parallel and designed to permit their being later run in series in the event that it is decided later to substitute a zone of some higher pressure to replace the present intermediate one.

One 4 m.g.d. centrifugal pump operating at 490 r.p.m. designed for a total lift of 254 feet and driven by a 300 H.P. marine type gasoline engine: The gasoline driven reserve unit has been installed to provide pumping facilities in case of failure of electric service.

The question of continuity of service was considered of first importance in the design of the station. With this end in view the Edison Company has installed duplicate sets of three transformers to serve the station. The current reaches these at 6600 volts from the Livingston power station through three main feeders. Two of these come direct from the main station at Livingston, while the third is connected to the Atlantic substation where, through a breakdown connection, reserve current from the Public Service Corporation, N. J., is available.

The Staten Island Edison Company's orders, in the event of a breakdown, call for first preference in service to be given to the main line electric transportation and municipal water supply.

The pumpage at the station during the first five months of 1929 has averaged 2.626 m.g.d. on the high service and 0.362 m.g.d. on the intermediate service. The kilowatt hours consumed during this period have averaged 104,160 per month, the average monthly cost for current being $1,324.53.

In connection with the question of continuity of service it is interesting to note that, while there have been several interruptions during thunder storms, there has been no time when the station was shut down for this cause for more than seven minutes.

FAILURE OF A 48-INCH CAST IRON MAIN UNDER EARTH PRESSURE[1]

By William W. Brush[2]

The object of this paper is not primarily to describe the failure of a water main under earth pressure, but the writer desires to use this failure as an object lesson or warning against installing pipe lines with more than about 15 feet of earth cover without providing additional thickness of pipe wall to withstand the earth pressure. The writer has heard numerous expressions of the opinion that when earth is backfilled in a pipe trench, it forms an arch and prevents the full load from the weight of the earth bearing on the pipe. This opinion does not appear to be supported by either experiment or experience and the observed conditions as to breakage of pipes in 2000 feet of 48-inch main laid in 1891 and in 3500 feet of a double line of 48-inch main laid in 1895 the wall thickness being 1 inch. The failure of these pipes has been effectively described by Joseph Goodman in *Engineering News-Record* of August 25, 1927 and only a brief outline will be given herein.

From the Kings County line to Ridgewood pumping station, about 4600 feet, the old Brooklyn Water Supply was carried in a 10-foot brick conduit constructed in 1857 and in a single 48-inch pipe 13.5 feet to the south and a double line of 48-inch pipe 18.5 feet and 25 feet, respectively, to the north, the distance given being between center lines. The pipes were laid about 2 feet above the flow line of the brick conduit. The hydraulic grade was at about the top of the pipes. The soil is a clean sand and water bearing with the water level about the top of the pipes. The depth of cover for a distance of about 3500 feet varied from 9 to 28 feet and was to be raised to 30 feet in grading for a proposed roadway. Computations of the strength of the pipe as an arch indicated a safe limit of cover of 9 feet. A 6-foot reinforced concrete circular conduit was planned to

[1] Presented before the Toronto Convention, June, 28, 1929.

[2] Chief Engineer of Water Supply, Department of Water Supply, Gas and Electricity, New York, N. Y.

take the place of the 48-inch pipes, two of which were to be retained for emergency service and one removed.

During construction it was found that many pipes were cracked, there being 59 cracked lengths on the southerly line in a distance of 2000 feet, while 32 were cracked in 3400 feet of pipe removed and 11 in the most northerly line. The cracks were old ones and came generally in the sections lying under street crossings with cover up to 28 feet. Some of the pipes were cracked top and bottom, a few on the sides and more on the top or bottom only.

The cracking of these pipes is an unusual demonstration of the necessity of designing pipe lines to safely carry, when empty, the full earth load due to deep cover and that no dependence should be placed either on the supporting power of the earth pressure on the side or on the so-called arch action of the earth above the pipe. Fortunately there are not many cases of pipe laid with earth cover of over 15 feet, but if such cover be used the pipe wall thickness should be based on the earth load and even for lighter cover, if very thin pipe is to be used.

OPERATING EXPERIENCES WITH A NEW AUTOMATIC RESIDUAL CHLORINE RECORDER AND CONTROLLER[1]

By J. Westford Cutler[2] and Frank W. Green[3]

Among thousands of processes and the apparatus connected with them, the art of chlorination has become well established in the minds of the water works profession. Chlorination was started with the use of very crude equipment. Step by step this equipment was perfected. Vacuum types of equipment replaced pressure types. Automatic equipment which varied the flow of chlorine in proportion to the flow of water became available and offered a distinct advance over manual types.

When chlorine is added to water a certain amount is absorbed by substances in the water in addition to that required for the killing of bacteria. If more chlorine has been added than is required for such absorption there will be an excess which is commonly termed "residual chlorine." This residual is used as a safety factor, and because this excess is easily measured by the use of orthotolidin, it has been generally accepted as a standard control in water purification work. The difference between chlorine applied and chlorine residual represents the chlorine demand of the water and this chlorine demand varies over wide limits. In the light of these facts, a desire arose for a perfect control system whereby chlorination was accomplished not only automatically in proportion to the flow of water, but in proportion to the chlorine demand, and with a certainty which would stand the test of legal cross questioning. It is apparent that such a control equipment would be a most useful tool in water works operation. Heretofore automatic equipment, although far better than manual, has not been the perfect control system. All variables involved in water treatment were not covered. Automatic equipment would compensate for changes in flow or pumpage, but

[1] To be presented before the St. Louis Convention, June 6, 1930.

[2] Experimental Engineer, Wallace and Tiernan Co. Inc., Newark, N. J.

[3] Superintendent of Filtration and Pumping, Passaic Consolidated Water Company, Little Falls, N. J.

not for any variation in the chlorine consumption of the water itself. It was necessary for the chemist to detect this change in chlorine demand by tests, and then manually adjust the chlorine dosage.

Few plants are able to use a constant chlorine dose, day in and day out, over long periods of time, and obtain a constant residual, because of the changes in flow and in demand. In order to be sure of a residual at all times various means are resorted to, such as carrying an overdose of chlorine; maintaining very careful supervision with frequent tests; or, in an increasing number of cases, applying automatic equipment to care for variations in flow. Where conditions are unusually erratic all three of these means are used. With all these precautions demand may still not be properly taken care of and there is no assurance on the part of those responsible for the character of the water delivered to the public that a residual has been maintained in every gallon of water delivered by their system. To overcome these difficulties the functions of the chlorine control equipment are: (1) It must automatically care for flow changes in the water treated. (2) It must adjust automatically the dosage for chlorine demand. (3) It must provide a legal 24 hour record. How these functions are performed in the new automatic residual recorder and controller will be described.

THE NEW AUTOMATIC RECORDER AND CONTROLLER

The world was benefitted when the great tool known as the photo-electric cell was perfected. Vastly complicated mechanical devices have been developed in and around these light sensitive cells, such as talking moving pictures, television, automatic counters, and high speed sorting machines for color, size or shape. These are only a few of the vast quantity of devices wherein the photo-electric cell is fundamental. These cells are obtainable in all sizes, shapes and kinds and a large majority are designed for special purposes wherein particular qualities are built into the cell so that it may perform a particular duty.

The cell which is the backbone of the Wallace & Tiernan residual control apparatus is of still another category and was selected for its ability to pass a sufficient amount of current to operate the equipment in its circuit without additional amplification. The equipment is essentially simple, both in design and in operation. The electrical units and electrical circuits are not complicated. It has been found most practical to use an intermittent system wherein a record is

made, chlorine dosage adjusted, and everything turned off for a period of time before a repetition of this cycle. The adjusting of the length of time between cycles is at the discretion of the operator.

There are four principal parts to one cycle of the apparatus. An electric motor starts and runs the machine through these four parts in their proper order and stops for the desired time interval. They may be listed as follows:

1. A light source must provide illumination in a manner which enables the photo-electric cell to measure and compare the color of the solution.
2. A mechanical relation must be set up which corresponds with this measurement.
3. The above mechanical relation must operate a pen on a chart and adjust the chlorinator.
4. The apparatus must automatically obtain for itself a new and fresh sample of treated water and add the proper amount of orthotolidin at the proper point.

In order that these various departments perform their action in the proper order, the equipment is arranged to operate from two shafts, geared to each other with an 8 to 1 ratio. The slowest of these shafts makes one revolution for a complete cycle. Bearing this in mind, the following description of these four parts becomes clearer.

Description of Unit

Part 1. The photo-electric cell is of the type known as a glow tube or trigger type cell. It resembles a valve in a water line. It is connected in an electrical circuit and when sufficient light intensity strikes it, it will open, allowing a current to pass, just as opening a valve allows water to flow. If a light is gradually increased in intensity there will be a point in the course of this increase in light at which the photo-electric cell will pass a current. In circuit with the light is a rheostat and battery and this light shines into the photo-electric cell. As the rheostat is revolved the light will get brighter and brighter to a point where the photo-electric cell fires. With no obstruction between the light and the photo-electric cell it was found, that the angle through which the rheostat turned in order to actuate the cell, was always approximately the same; therefore, it is possible to use this angle as a measure of the conditions through which the light must pass on its way to the photo-electric cell. (See figure 1.)

The solution containers are therefore placed between the light and the photo-electric cell. In order to eliminate certain variables it is wise to incorporate a comparison between clear water plus a standard and water with the orthotolidin. By so doing slight changes in turbidity of the water or slight

changes in the natural color are compensated for, as are also changes in the equipment itself, such as weakened batteries, aging of the light source, or a physical change in the photo-electric cell.

In figure 2 there is illustrated the pair of solution containers located between the light and the photo-electric cell. They are bored out of a hard rubber block and glass ends are fitted. The heavy line indicates the containers in their first position. While in this position the rheostat revolves from A around to B, gradually increasing the intensity of the light, until it has reached a point where the necessary illumination has penetrated the glass standard and

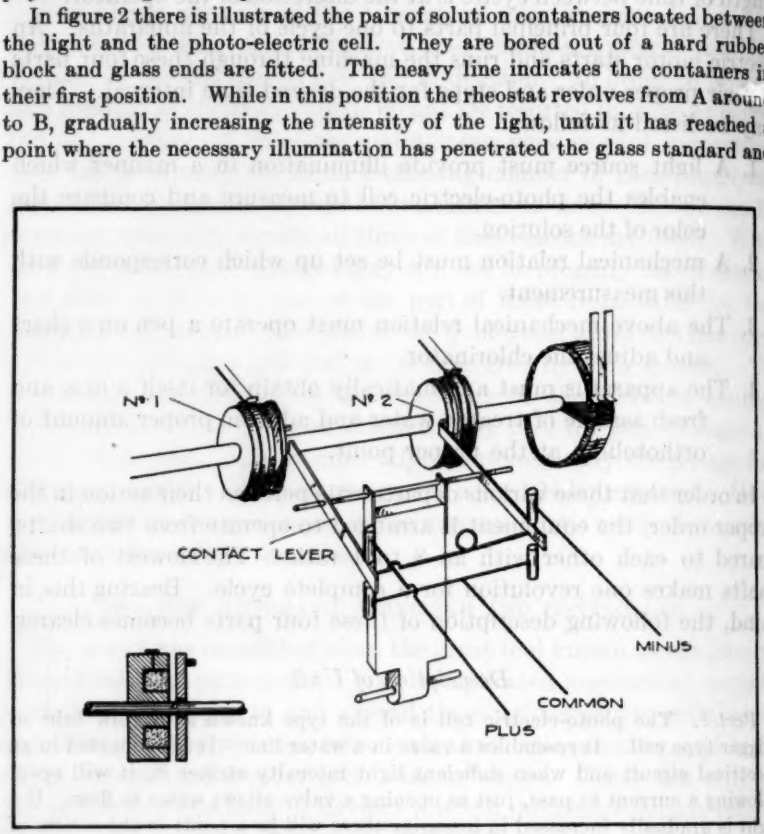

FIG. 1

the clear water sample, actuating the photo-electric cell. The solution containers then move over to a point where the second sample is in the path of light. This sample has had time to develop the natural ortho tolidin color and again the rheostat revolves from A to B, gradually increasing the light to a point where the photo-electric cell fires again making a comparison between the two solutions. This comparison can be expressed as an angle on the rheostat and if the same angle was turned for each there would be zero difference and the residual concentration would be the equivalent of the standard glass and no adjustment of the chlorinator would be required.

Part 2. Having made this angular comparison it remains to transfer the angular difference mechanically to a set of contacts which will operate the recorder and adjust the chlorinator.

Referring to figure 3, there is attached to the same shaft as the rheostat a pair of magnetic clutches, the armatures of which contain a small pin. Each of these clutches is so constructed and connected electrically that the armature with the pin revolves only when the magnet is energized, and as soon as the photo-electric cell fires, the armature of the clutch is dropped. The two clutches correspond respectively to the two solutions in the solution container. Each pin starts from a zero point at the time the light turns on, and continues during the time that the light increases to a point where the cell passes a

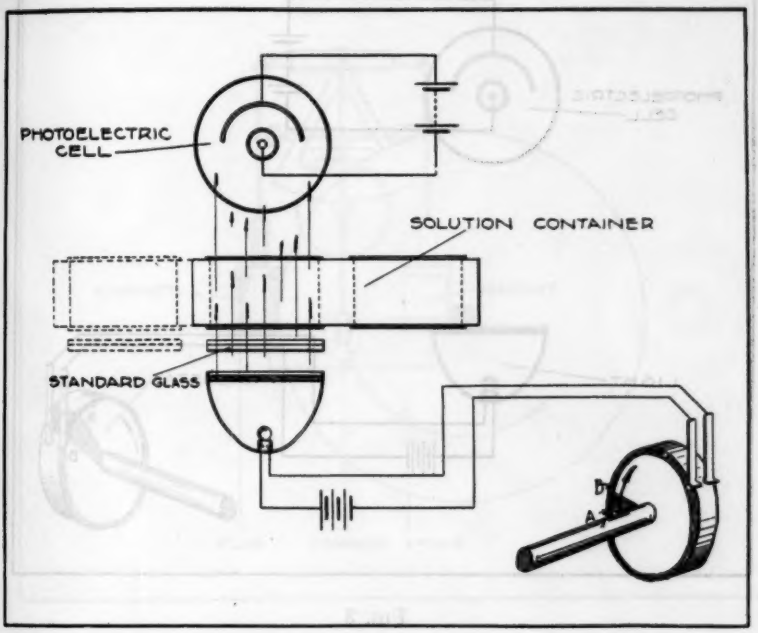

FIG. 2

current. Each pin will travel, therefore, through an angle equal to the angle on the rheostat, and the position of the pin is a measure of the solution. Thus the pin of No. 1 clutch measures off its angle for the clear water and standard glass, and then the pin of No. 2 clutch measures off the angle for the orthotolidin sample. After these two measurements have been made both clutches operate together, and the pins are revolved in their relative position until they strike contact levers as illustrated. Naturally, if the angular measurements are different one pin will strike its contact lever before the other. Electrical connections thus made are transferred in a parallel circuit to the chart and to the electrical device operating the chlorinator.

The circuit is a simple three wire circuit wherein one wire is common to both plus and minus motions and the contact levers strike contacts which cause an increase or decrease, according to the angular measurement previously described. Thus we have an arrangement wherein a large angular difference between the two solutions will cause a longer period of contact, plus or minus, than a shorter angular difference, and for this reason our recorder will be energized for a length of time in proportion to the angular difference of the two solutions, and the adjustment of the chlorinator will also be in proportion to this error in residual with respect to the required standard.

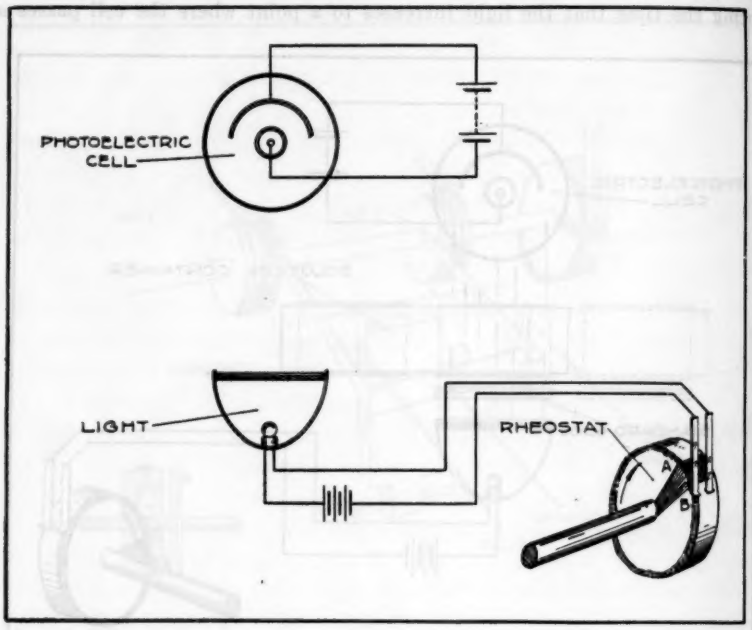

FIG. 3

Part 3. For the recorder a device has been designed which will draw a single line on a circular chart. As long as there is no difference between the standard and the residual no lines other than this center line will appear on the chart, but, should there be a difference, the plus magnet or minus magnet of figure 4 will be energized, causing short lines at right angles to be drawn. The length of these lines is proportional to the difference of the two solutions and represents both the amount of residual with respect to the standard and the amount of adjustment that the chlorinator has made. For purposes of control this simple chart has been deemed adequate. It is not possible to say that the length of these lines presents a definite part per million error in the residual, but they give a relative idea to the operator and adjustments can be made for different conditions.

In parallel with the recorder is the controlling device for the chlorinator. The work to date has been with a standard automatic vacuum chlorinator which is designed to operate from venturi meters, Pitot tubes, and the like, and which adopts itself very easily to electrical control by means of the device illustrated in figure 5. This device would be known as a vacuum controller and inasmuch as the chlorinator operates on an orifice differential of 8 inches, it is designed to control a vacuum between zero and 8 inches. A small tank about 12 inches square and 2 inches thick is used which is filled with water to a level close to the top. This water level is automatically maintained. In this tank a lever arm is placed which can operate over a 90° arc. This lever is

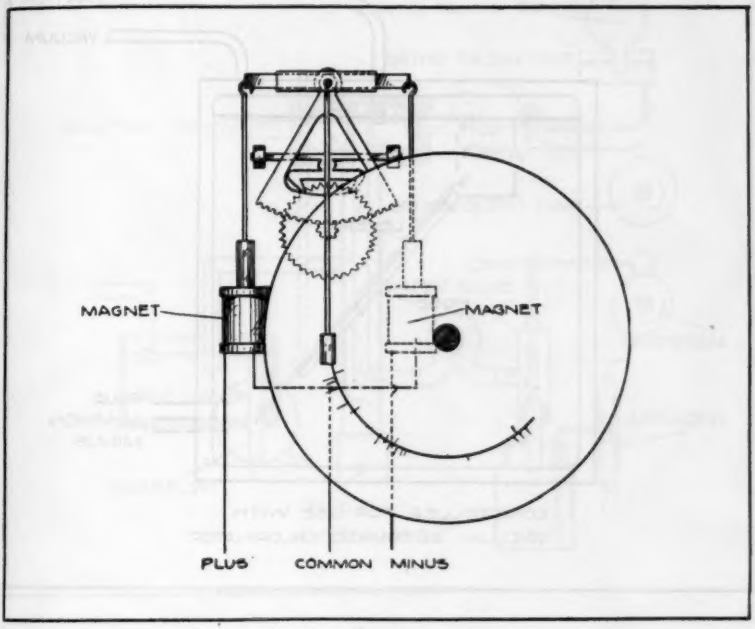

FIG. 4

operated by an electrical device which will run in two directions as directed by the switching of figure 3. Attached to the lever arm is a flexible tube connected to a vent on the outside of the tank. Suction is applied as indicated causing air to bubble through this tube and the distance "h" from the level of the water to the end of the flexible tube is a measure of the vacuum in the top of the tank. This is connected by a pipe to the chlorinator. By running this lever through this 90° arc complete range of flow on the chlorinator is obtainable. The device as actually constructed contains limiting screws which prevent automatic adjustment except between the two limits, therein offering a safety check on the machine.

Part 4. In the last part of the cycle it is required to wash out the old solution, refill the containers, and add orthotolidin to one of them, so that the color may develop during the time interval between cycles. Figure 6 illustrates the apparatus involved.

A constant stream of water is allowed to flow into the sample water box. The aspirator is also running constantly creating a vacuum in a jar. At the proper time in the cycle the water cam opens the water valve which applies the vacuum directly to the solution containers, drawing out the old water in them,

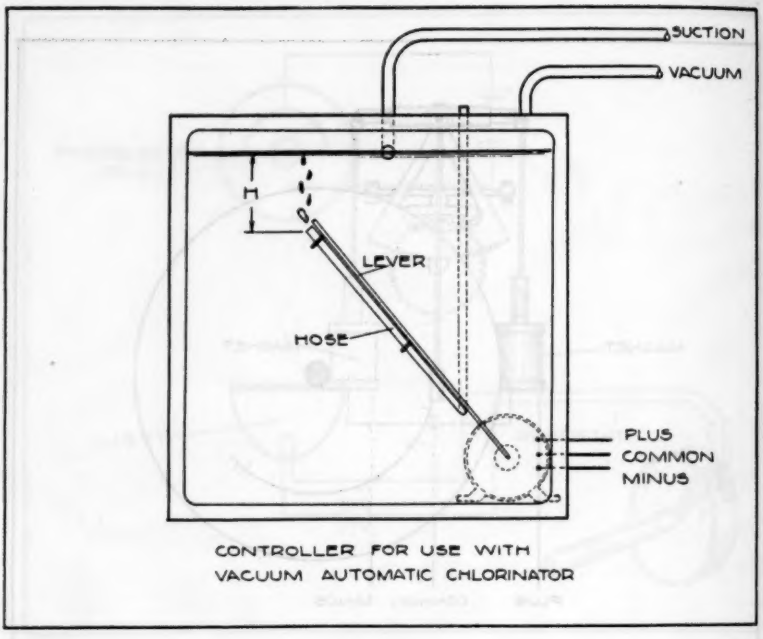

FIG. 5

rinsing them thoroughly, and leaving a fresh sample when the water valve closes. This valve is open long enough for a volume of water to pass through the containers equal to at least ten times their volume. This gives a thoroughly new and fresh sample. A few degrees after the water valve closes, the orthotolidin cam opens the orthotolidin valve which permits about 2 cubic centimeters of orthotolidin to flow into the proper solution container from the constant level box, as illustrated. No sooner is this completed than the motor shuts off and the machine is dormant for the desired time period.

Operating Results

The development of this machine has been the work of something over four years, during the course of which four models have been built and operated.

The first practical installation was made at Little Falls, New Jersey, in August 1929, at the plant of the Passaic Consolidated Water Company. This plant has a 75 m.g.d. output wherein a river water

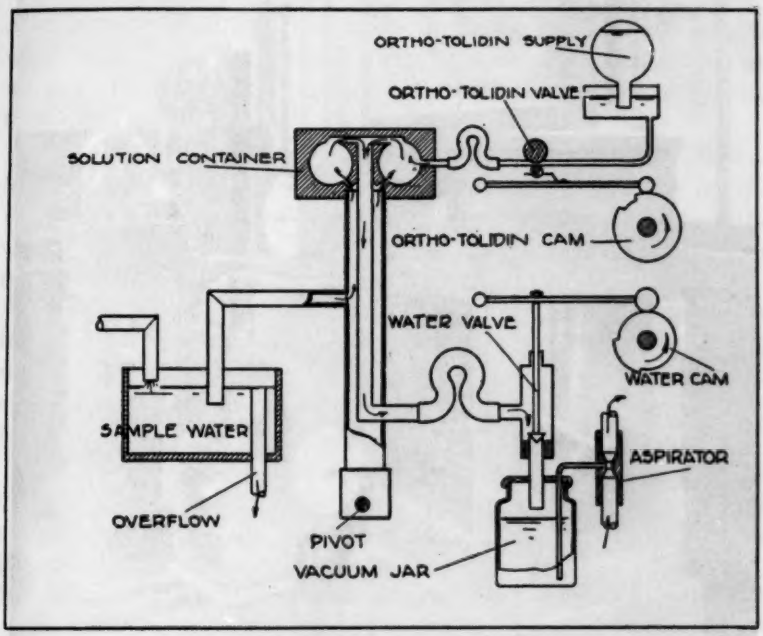

FIG. 6

is filtered, chlorinated, and pumped to Paterson, Passaic, and several other communities.

At first the installation was made taking a sample of the entire output of the plant and making a record of the variations in residual of the delivered water. Between August and the end of December, 1929, after several minor changes were found necessary, it was sufficiently proved that the apparatus was suitable and safe to attach to a chlorinator and proceed with the original design—that of control of chlorination by residual. Therefore, in January the equipment

was moved and attached to an automatic chlorinator. This was to control the chlorination of a certain section of the Little Falls Station. The output from a 63 m.g.d. battery of gravity filters flows

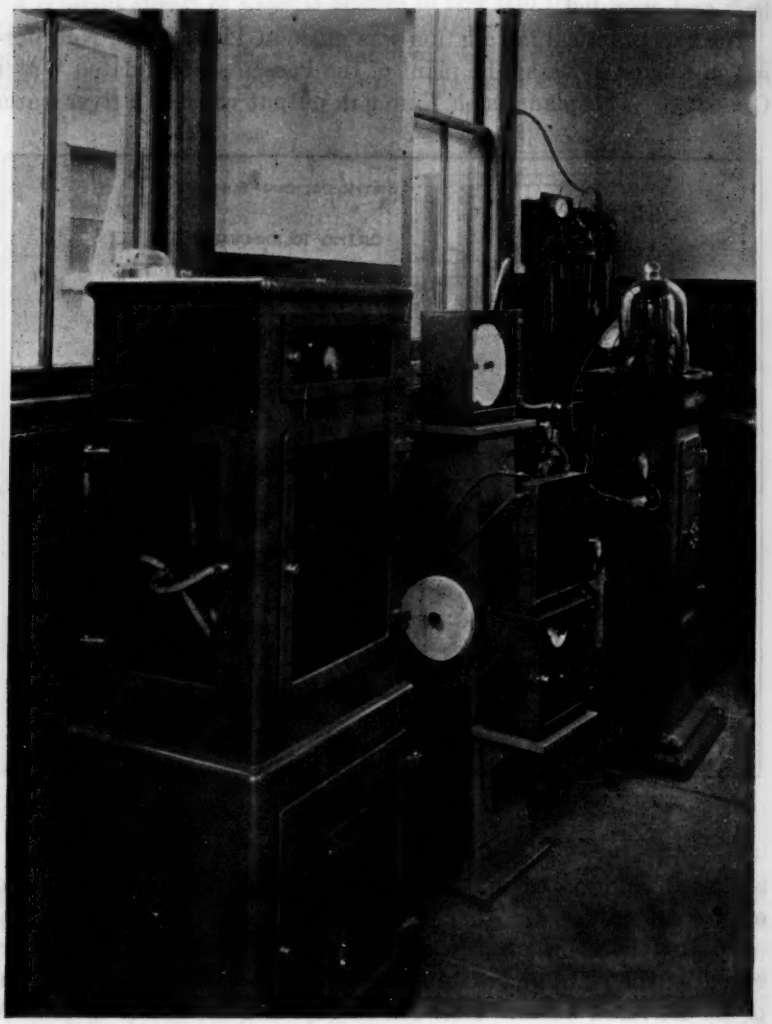

FIG. 7

by gravity some several hundred feet to the pumping station and in this suction line there are two chlorine applications, the sum of which constitutes chlorination for this section of the system.

First, some 125 pounds of chlorine are added to the water from a series of electrolytic cells and on top of this an auxiliary chlorinator adds a variable amount of chlorine of approximately 50 pounds average as an adjustable trimmer. This adjustable trimmer supply of chlorine is connected to the residual control outfit. The pump discharge returns to a point very near the location of the chlorinators and a sample line is brought over to the residual controller. In this manner there is a lag of ten minutes between the point of application of chlorine and the supply box at the rear of the residual controller. After correcting a number of minor mechanical difficulties, some of which were due to an unusual current source of 220 volts D.C. for which the machine was not designed, the entire assembly of apparatus functioned satisfactorily.

Manual orthotolidin tests, taken as a check on the apparatus at frequent intervals, showed that the controller was picking up the variations in demand and flow. An 80-pound chlorine meter on the chlorinator was frequently called upon to change over its entire scale in response to these demand changes.

The ten minute lag between application and sample, while annoying at times, was found to have no serious effect upon the final result. It was very gratifying to note on several occasions that unexpected changes in output from the chlorine cells were compensated for very promptly by the controller.

Some little difficulty was encountered with the long interval required to develop color in the cold water flowing during the months of January and February, but the use of a stronger concentration of the orthotolidin solution and slightly warming the water corrected this condition without impairing the quality of the results obtained.

Careful observations by officials of the Little Falls Plant showed satisfactory control between 0.18 and 0.21 p.p.m. At various times the standard glass was changed rendering a different range of control.

Early in April, 1930 another installation was made in a waterworks of different character—that of the municipal plant at Rahway, New Jersey. This plant pumps less than 6 million gallons per day and desires to maintain a residual between 0.05 and 0.1 p.p.m. in fear of taste difficulties frequently encountered with high residuals. This installation was made in a 30-foot run of exposed filter effluent line, running from the filters to a covered clear well. The chlorine was applied at the beginning of this 30-foot 24-inch line and a sample was taken about 25 feet beyond the point of application. This was

necessary because of a two-hour detention in the clear well before a sample could be obtained. The velocity in this pipe averages about 2 feet per second and there seemed to be sufficient mixing for the sample to be a true one at the machine. In order to be certain of time for chlorine absorption a retention of 5 minutes was added to this sample before it entered the machine. Time for development of color was of course allowed in the machine itself. Operating on this short line a very snappy control was obtained and the standard was set for approximately 0.15 p.p.m. in order to control a 0.05 p.p.m. residual after the 2-hour interval. While this installation has not been in use very long the evidence available to date assures its success.

The system of residual control is adaptable in many ways other than the two just mentioned. It may be used as a warning of approaching pollution by locating the machine upstream and the chlorinator far enough downstream to protect the water supply when the controller indicates the need of increased chlorination to protect the water. The design is such that even miles may intervene between controller and chlorinator. For Great Lakes water supplies this feature offers innumerable arrangements to indicate points of sudden high demand and protect the consumer. Large savings in chlorine will often result and a great deal of responsibility from a legal point of view can be automatically taken care of. It may even be contended that the record offered by this equipment, and the legal significance thereof, will be its greatest advantage to waterworks users.

Not only, however, is the machine adaptable to chlorination. Experiments are already well under way for the application of this machine to hydrogen ion control. There is no question, but that it could be used in the regulation of turbidity or natural color in the water, and several cases have been brought to the attention of the developers for industrial uses.

The art of chlorination has again progressed. Another great tool has been added to the list of photo-electric devices. Another advance has been made in the protection of public health. As a process it is in a well developed stage. As a mechanical device, it is functioning well and will continually be impoved as experience indicates.

PUMPING STATION EQUIPMENT, OSHAWA, ONT.[1]

By W. C. Smith[2]

The Oshawa water works plant has enjoyed a rather unique development on account of growth from a small town into a city of nearly 30,000 people in a short space of years. The plant was first conceived and installed under the direction of Willis Chipman, in 1904, when a town of 4,300 people expended nearly a quarter of a million dollars on a steam operated pumping plant and a gridiron system of limited proportions, surmounted with a cylindrical standpipe of 65,000 imperial gallons capacity. The consumption grew until, in the year 1922, when I first took charge of the system, the total annual pumpage was 266,000,000 gallons, with an average daily demand of 730,000 imperial gallons for a population of 12,780 people. The plant at that time consisted of two 90 H.P. horizontal return tube boilers, one cross compound Corliss horizontal high-duty steam pump with a capacity of about 600 gallons per minute, one duplex Snow steam pump with a capacity of 1000 gallons per minute, one centrifugal pump with a capacity of 1000 gallons per minute, driven by a 4000 volt motor, and one centrifugal pump of 1000 gallon capacity driven by a 550 volt motor of 175 H.P. capacity. The above constituted all the high-head plant for delivery of the water from the pumping station on the lakeshore to the City. In addition, the low-head or filter plant equipment was as follows: two centrifugal pumps with a capacity of 650 gallons per minute each, driven by 10 H.P. 550 volt motors, one centrifugal pump with a capacity of 1300 gallons per minute, driven by a 25 H.P. motor and also by a 25 H.P. Sterling gasoline engine as an auxiliary.

The plant as outlined, was amply sufficient for the town up to the year 1922, when it was found to be inadequate. Steps were then taken to improve it. The 4000 volt motor unit was replaced with a new pump and motor unit purchased under rigid specifications as to efficiency guarantees, and mechanical features, and having a rated

[1] Presented before the Canadian Section meeting, March 12, 1930.

[2] City Engineer, Oshawa, Ontario, Canada.

capacity of 1100 gallons per minute against a 340 foot head, with a capacity of 1250 gallons per minute against a 300 foot head, and driven by a 150 H.P. 550 volt, 1800 R.P.M. motor. While the guarantee of efficiency on this pump was 77 per cent, the actual efficiency developed on careful test running, was from 81½ to 83 per cent. When the old standpipe required a head of slightly less than 290 feet, the average delivery from the pump exceeded 1300 gallons per minute. This unit was installed early in the year 1924 when the City had reached a population of 16,600 people.

In 1926, the population had increased to 17,400 and the water demand to an average of 1,320,000 gallons per day. To meet this situation a duplicate unit of the same make was installed in the place of the original 175 H.P. unit. These two new units gave perfect satisfaction, and their efficient performance is evidenced by the following: The cost of pumping 1,000,000 gallons against an average head of 290 feet in the year 1923, with the old electrical pumps, was $15.40, whereas, following the installation of the new units, the average cost of delivery of 1,000,000 gallons under a head of 310 feet, was $11.00, indicating a saving by the improved efficiency of the plant, of $4.40 per 1,000,000 gallons, or $2,100.00 per year in the cost of power, on the pumpage of that time (neglecting the increased head). This saving soon amounted to a sum sufficient to pay completely for new pumping equipment.

In 1924 a further important unit in the system was added in the form of an elevated water tank, with a capacity of 500,000 imperial gallons. This item might not be considered to come under the classification of pumping station equipment, but it was erected to relieve the pumping station of spasmodic loads as well as to increase the pressure throughout the system and the general safety of the system through storage. The water tower was found to be of considerable value to the whole system and to the pumping station in particular, as it permitted the installation of pumps calculated to take care of the ordinary demands of the city, while the water tower provided for the short periods of abnormal or emergency demand. Any water delivered from the tank during a short period of extra demand, was immediately replaced, of course, to the tank so that it has been kept in an approximately full condition at all times. The construction of the tower was a major factor in the reduction of fire insurance rates in the city.

MORE RECENT PLANT DEVELOPMENT

Due to the growth of the city, although the per capita consumption was maintained at an average of 75 gallons per day by adhering to a general metering policy, the city's consumption grew to an average of 1,500,000 gallons per day and it became necessary to augment the pumping capacity. The fact that per capita consumption has been maintained at the low figure indicated, is evidence of the great effect of meters on a system and pumping station equipments. After consultation with the makers of the pump installed in 1924, it was found that a capacity more than sufficient for the demand and amounting to 1700 gallons per minute was attainable by simply changing the pump impellors and substituting a 200 H.P. motor which fitted into the frame of the original motor. The change was accordingly made and proved to be economical in that it did not occasion any re-arrangement of the pipe layout and did not disturb the plant at all until the new impellors, etc., were delivered. Furthermore, it was found, on carefully testing the altered unit, that the original efficiencies were well maintained. This gradual stepping up of plant capacity instead of adding much larger units, was adopted, as it was impossible to determine the rate of future demand. By keeping the plant at a reasonably safe capacity heavy increases in the peak demand for power, at a rate of $30.00 per horse power year, were avoided.

At present the demand for water has increased to 2,000,000 gallons per day, and a similar change is contemplated in the other unit installed, as outlined above.

With the increasing demand careful consideration is being given, and a report has already been submitted to the Commission recommending an alteration of Unit # 2, and the installation of a new unit with a capacity of 3000 gallons per minute, and driven by a 350 H.P. 4,000 volt motor. It is felt that it is preferable to expand the plant further with 4,000 volt motive equipment, thereby saving transformer losses and improving power factor conditions, as well as simplifying switchboard equipment.

NEW AUXILIARY PLANT

Reference is here made to the steam plant which was maintained at all times in a condition ready to operate at a moment's notice, and which was operated on all fire alarms registered at the pumping station and on all emergency occasions, such as interruptions in the

hydro power. The steam plant was totally inadequate and was very expensive to maintain and operate. In order that the situation might be improved, an analysis was made to determine the type and capacity of auxiliary plant best suited to the needs of the city. This analysis included a study of various types of plant, including a gasoline engine driven unit, a steam turbine driven unit, a reciprocating steam engine driven generator and electrically operated pumps to suit, and a Diesel engine driven pump. In comparing the various types of plant outlined, a uniformity of conditions was adopted as follows: pump capacity 3,000 imp. gals. per minute; motive power output 350 H.P. The capacity of 3,000 gallons per minute was adopted because of the fact that at that time it represented the best capacity obtainable from a gasoline driven pump, represented in the power available from the then largest stationary gasoline engine built. Shortly after the analysis was made, it was ascertained that the Sterling Engine Company were building an engine for marine purposes with a developed horse power of 565 and a guarantee of continuous delivery of 475 B.H.P. at the coupling. The development of this engine was opportune as it enabled us to accomplish what we were aiming at much better than the 350 H.P. engine permitted, in that it provided sufficient power to permit the driving of the auxiliary low head or filter plant pump by the power derived from the main engine, as indicated hereafter.

In referring to the analysis of the various types of plant considered, it should be mentioned that they were first of all put on an equal basis as to output and requirements; and the costs of the various types of plant were considered together with the costs of installation, depreciation, building requirements, operating costs including fuel (gasoline, fuel oil or coal), operators' wages, cost of maintenance, piping installations and alterations.

Table 1 indicates in brief form the result of the analysis. It shows that up to a service requirement of slightly more than 500 hours per year, a gasoline engine driven unit indicates a considerable, though decreasing, economy over any of the other types of plant considered. At a point somewhat above 500 hours use per year, the Diesel driven pump indicates a saving over any other of the types considered, and continues to show increasingly greater economies as the operating period increases.

Our experience in operating the auxiliary plant over a considerable number of years, shows that the average operating period does not

TABLE 1

Comparison of several varieties of plant installation including filter pump; comparative total costs and operating costs, including fixed charges, etc.

Capacity 3,000 Imp. G.p.m.—motive power, 350 H.P.

TYPE OF PLANT	COST OF PLANT INSTALLED	TOTAL ANNUAL COSTS, IN DOLLARS, AT VARIOUS NUMBERS OF HOURS OPERATION PER YEAR								COST PER H.P. HOUR AT 7,000 HOURS PER YEAR
		50	100	200	500	1,000	2,000	4,000	7,000	
	dollars									*cents*
1. Gasoline driven pump	16,000.00	2,250	2,550	3,150	4,950	7,950	13,950	25,950	43,850	2.1
2. Steam turbine driven pump	21,000.00	4,600	4,850	5,350	6,850	9,350	14,350	24,350	39,350	1.87
3. Diesel driven pump	35,000.00	4,000	4,150	4,450	5,350	6,850	9,850	15,850	24,850	1.15
4. Reciprocating steam engine driven generator	32,000.00	5,475	5,750	6,300	7,950	10,700	16,200	27,200	43,700	2.1

For purposes of comparison, it might be stated that an electrically driven pump of similar capacity, would cost about $12,000.00 per year for a 7,000-hour operation or about 00.55 cent per H.P. hour.

The above schedule illustrates the yearly costs of the several varieties of plant at various operating periods, but it should be noted that the auxiliary plant would only be operated during emergencies and also about half an hour per week to ensure working condition. Our actual emergency operation varies from 50 to 75 hours per year, so that the probable yearly operation should not exceed 100 hours.

The schedule has been extended to indicate the points at which the economies of the various plants become evident. The gasoline unit is superior up to an operation of about 10 hours per week, after which, the Diesel engine economies are evident.

exceed 100 hours per year, under which condition the 350 H.P. gasoline driven unit would cost $25.50 per hour of operation including fuel, oil, attendance, fixed charges, depreciation, building room, etc., while the Diesel unit would cost $41.50, and the steam plant would cost considerably more.

The above figures are based upon local conditions, with gasoline at 20 cents per gallon, fuel oil at 12 cents and coal at $7.55 per ton in the bunkers. These have been reduced to round numbers for general ease of understanding and to show that the analysis is not intended to indicate more than a general comparison under the local conditions.

New Sterling gasoline engine drive

As a result of submissions to the Water Works Commission, the old Corliss cross compound high duty pumping unit was removed and replaced by a 12-inch, 2 stage centrifugal pump with a guaranteed efficiency of 80 per cent and a capacity of 3750 imperial g.p.m. against a total head of 300 feet, direct connected through flexible couplings with a 550 H.P., 1200 r.p.m. Sterling "Viking-11" 8 cylinder gasoline engine. This engine is unique in several particulars. It is the first engine of its size installed on the Continent of North America or anywhere in the world so far as we are aware, in stationary work of any kind. While the rating of the engine is 550 B.H.P., with a guaranteed continuous load capacity of 450 H.P., still the engine developed under tests run by the writer on the factory test floor, 638 B.H.P. at 1200 r.p.m., at which point the water brake equipment failed and tests at higher capacity could not be run.

This engine will prove, I believe, to be of great interest to water works engineers, as it opens up an entirely new range for the development of auxiliary or stand-by plant at moderate first cost and reasonable operating costs. In recent years, gasoline engines have become so reliable that they are now readily recognized by the Fire Underwriters as a suitable power plant for water works auxiliary.

The Sterling "Viking-11" 8 Cylinder engine weighs 7,850 pounds, occupies floor space of 3 by 9 feet, and stands about 6 feet high. The pump and engine complete occupy floor space of 16 feet 10½ inches by 3 feet 6 inches, whereas the old cross compound Corliss engine and pump occupied a floor space of 34 feet by 12.5 feet, or seven times the area required for the new unit.

The new engine is rather remarkable and perhaps a general de-

scription of some of the features of the largest stationary gasoline engine, at least on this continent, might be of some interest.

The fuel is drawn from storage tanks external to the building and is delivered through two fuel pumps to four carburetors which are equipped with protection against backfire and which are located so that the fuel is delivered into the cylinders with the shortest possible fuel travel. The four carburetors acting as one insure an even distribution of fuel to all cylinders at all ranges of engine speed and load. This is obviously very important in an engine with eight cylinders in line, each with a bore of 8 inches and a stroke of 9 inches and running at 1200 r.p.m.

The dual valve principle embodying two fuel and exhaust ports per cylinder, permits the admission of 50 per cent more fuel to the cylinders and an equal discharge of the burned gases with proportional efficiency. The valves being smaller are much less subject to warping and are more easily cooled.

The engine crank shaft is naturally very heavy as are also the connecting rods. At high speed this necessitates refined counterweighting opposite each crank throw and dynamic balancing to insure smooth or safe operation. The engine operates at all speeds and loads smoothly and with a total absence of vibration. The crank shaft bearings are perfectly fitted without shims. The bearing caps are fitted into shoulders on the crank case and are reinforced with heavy steel reinforcing caps. The aluminum pistons with bearings bridged to the head and deattached from the skirt, are fitted closely into the 8-inch cylinders. The pistons are fitted with four rings above the pin bearing and one below.

The engine is cooled by water drawn at the rate of 80 g.p.m. by a rotary gear pump on the engine, from the suction of the main pump. After leaving the circulating pump, the cooling water is first delivered to the lubricating oil cooler and filter (which treats the oil in the oil pressure system throughout the engine), and then to the various parts of the engine including the exhaust manifold, in the proper proportions to insure adequate cooling. A three-quarter inch stream is taken from the cooling water as it discharges from the engine, and is delivered into the 6-inch exhaust line at the outlet end of the manifold. This water is converted into steam and cools the exhaust line and assists in the silencing of the exhaust. Several types of exhaust silencers were proposed by the engine makers, but we installed one of our own simple design which reduces the normal

deafening exhaust to a pleasant hum audible for a short distance only. The silencer consists of a concrete pit underground, 4 feet square and 5 feet deep, into which the engine exhausts. The exhaust expands from the 6-inch pipe into this pit and, still expanding, is carried through 40 feet of 27-inch tile into a chamber similar to the first pit. The exhaust is then carried up the side of the pumphouse in a 12-inch flue from the top of which is emitted a white plume of steam and burned gases, with a not unpleasant hum.

The ignition is accomplished through four distributors, each of the four spark plugs in each cylinder being independently fired. The equipment includes two generators which operate the ignition system and charge the twelve volt storage batteries.

The engine is electrically started from the 12 volt storage batteries through two motors suitably geared to the fly wheel.

The instrument board is fully equipped with meters, gauges, starting button, throttle, etc. The running of the engine is remarkably simple considering its huge proportions. Starting is accomplished by simply pressing a button and opening the throttle, and the full load capacity is available in 15 seconds if necessary. In ordinary operation, however, we warm the engine up for about 30 seconds at about 400 r.p.m.

At a normal load, the engine consumes about 30 gallons of gasoline per hour carrying a load of 335 B.H.P. and requires about one gallon of lubricating oil per hour. This indicates a fuel consumption of about 0.09 gallon per B.H.P. hour.

The two stage 12-inch centrifugal pump is directly connected to the engine through flexible couplings. The pump sits above the level of the water in the clear well, and as we operate all the pumps in the plant without foot valves, it is necessary to prime the pump by exhausting the air from the pump housing and the suction line. To accomplish this, a 2-inch Koerting water jet exhauster is employed with very satisfactory results. A 2-inch brass calibrated "Sandiland flow indicator" was placed in the priming line near the ejector to give positive indication of the priming of the pump.

To facilitate the proper operation of the whole auxiliary plant at night with the electric power off, a one kilowatt D.C. generator driven by a 6-inch Pelton water wheel was installed complete with switchboard, meters, rheostat and lights. This small piece of apparatus has proven of great value as auxiliary to the pumphouse lighting system.

AUXILIARY LOW HEAD PLANT

Mention has been made above of a rather unique installation to operate as an auxiliary low head pump in the filter plant. This equipment consists of a 12-inch single stage centrifugal pump with a capacity of 3,000 imperial gallons per minute against a total head of 35 feet, and driven by a 24-inch double runner Pelton wheel through a flexible coupling, at 1,000 r.p.m. The Pelton wheel is actuated by water drawn through a 6-inch line from the delivery of the large high head auxiliary plant. It will be remembered that the capacity of the high head pump was 3,750 gallons per minute, 750 gallons of which are taken to operate the low head pump, and are returned to the clear well by gravity through the draught tube of the Pelton wheel, so that the 3,000 gallons capacity of the low head pump is equal to the amount of water delivered to the city by the high head auxiliary plant, the 750 gallons per minute making a continuous cycle within the plant.

The low head pump is located 17 feet above the pump well level and is primed by a 2-inch Koerting exhauster with flow indicator, in a manner similar to that employed in the high head plant. These exhausters have also been connected to all the other pumps in the plant for priming purposes.

We are now installing a duplicate of the low head pump just described, driven by a 40-h.p. motor, which will operate as a service pump in place of the two 10 H.P. low head pumps mentioned in the first part of the paper.

SERVICE INSTALLATION PRACTICE[1]

By Charles P. McGrath[2]

On April 15, 1924, the Department of Water Supply began the installation of service connections between the main and lot line. Previous to this date the work was done by licensed plumbers with the exception of the tapping of the main.

Applications for service connections are made to the permit department by licensed master plumbers who carry licenses with this department. Permits for connections to be laid in advance of pavement where no building is contemplated may be applied for by the owner. When the application is applied for, the plumber or owner is given a stake bearing the service connection number which he must place on the lot where he wishes the service to be installed.

The cost of installation of a service connection is paid for at the time of application, the cost varying with the size of connection and the width of the street. If two connections are laid on one trench a reduction of $5.00 on each connection is made. On streets which have two mains, and all connections in the one-half mile circle and all sleeve and valve connections on mains 24-inch and larger are charged for at cost plus 20 percent. A cash deposit amounting to the average cost of the particular job is made at the time of application and an extra charge or refund is made based on the actual cost of the job.

The service connection order is forwarded from the permit department to the office of the service installation department where the necessary information is transfered to the records of that department. They are then sorted as to location and sent to the nearest yard for installation.

The service connection orders are given to the service foremen who make inspection of the jobs. They find out whether the plumber

[1] Presented before the Central States Section meeting, September 20, 1929.

[2] Superintendent of Water Supply Yards, Department of Water Supply, Detroit, Mich.

has installed the lead between lot line and building and ascertain if the number of the stake corresponds to the number on the service connection order. They then measure up the number of feet of service pipe required and note if it is necessary to break the pavement. If they find the job ready for installation they so note on the order, if not they note the objection and return to the office. All jobs ready for installation are then turned over to the lead room where the connection is made up by a plumber, which consists of wiping the curb cock on one end of lead and tail piece on the other end.

If it requires the breaking of pavement to install the connection it is turned over to the concrete breaker foreman.

All jobs are pinned on a map when ready for installation and routes are made out keeping the jobs as close together as possible. Service connection orders are given to foremen with crew of 10 to 12 men transported by the use of a 1½ ton truck. They drop off their men at the various jobs. The number of men to a job depends on the length of the service. All jobs that involve breaking the pavement are backfilled and tamped and topped off with the old concrete by the service gang. In the course of ten days the concreting gang removes the old concrete, retamps ditch and concretes the hole. In heavy traffic streets the holes are concreted within two or three days and fast setting cement is used.

When the service connection is installed the service order showing the distribution of labor, material and cartage are forwarded to the service installation office where the cost is tabulated and the service connection order filled for future reference.

In November, 1925, the Department began experimenting with copper pipe for use on service connections. Copper was used for service connections in old dumps, under street car tracks and other places where lead pipe had caused trouble.

In October, 1928, the Department adopted the use of copper, and since that time 15 percent of the jobs are laid with it. It is thought the use of copper will show a steady increase.

The personnel of this department consists of a general foreman, an assistant foreman, seven service connection foremen on small services, two service connection foremen on large services, two air compressor operators, one concrete foreman and approximately 100 laborers.

The service installation office consists of one principal clerk, two senior clerks, four junior clerks and one typist.

OPERATING EXPERIENCES WITH A NEW WATER SOFTENING PLANT AT MARION, OHIO[1]

By Martin E. Flentje[2] and Charles Whysall[3]

The water softening plant of the Marion Ohio Water Company, a subsidiary of the Community Water Service Company of New York City, is unusual from several standpoints. Probably, first of all is the extreme hardness of the water being treated; secondly, the use of all steel construction above ground; and finally in the application of double carbonation to produce an effluent of low alkalinity.

Water is at present obtained from 14 wells in limestone, varying in depth from 140 to 225 feet. Motor driven pumps deliver the water to collecting troughs leading to a concrete basin. During passage through these troughs and while spraying over small aerators, the raw water loses some CO_2 gas, and the dissolved iron is oxidized. Oxidation and precipitation of the iron results in an apparent turbidity of 150 p.p.m. in the collecting basin. Typical partial analyses of the well waters is given in table 1.

The water is pumped to the two 30-foot diameter mixing tanks, receiving on its way the milk of lime prepared in the headhouse. Browning-Montgomery chemical dry feeders are used. A 100 g.p.m. capacity ejector adds the lime water to the water to be treated, while the former soda ash injector has been replaced by a small centrifugal pump. Soda ash is applied at the top of the second mixing chamber. Marble Cliff (Ohio) pebble lime and Solvay soda ash are used. The mixing basins are 24 feet in height, as are all other basins. A single paddle is located near the bottom, and is driven by a variable speed motor. Water enters tangentially at the bottom, spirals upward, overflows into the bottom of the second basin and repeats the process. The retention period in the mixing basins is 4 to 5 hours at the present rate of flow, with a minimum retention of one hour at plant capacity.

[1] Presented before the Toronto Convention, June 27, 1929.

[2] Superintendent of Purification, Community Water Service Company, New York, N. Y.

[3] Chemist in Charge, Marion Water Company, Marion, Ohio.

From mixing chambers, the water flows to the 120-foot diameter Dorr Clarifier, flowing into the 30 foot stilling chamber in the center

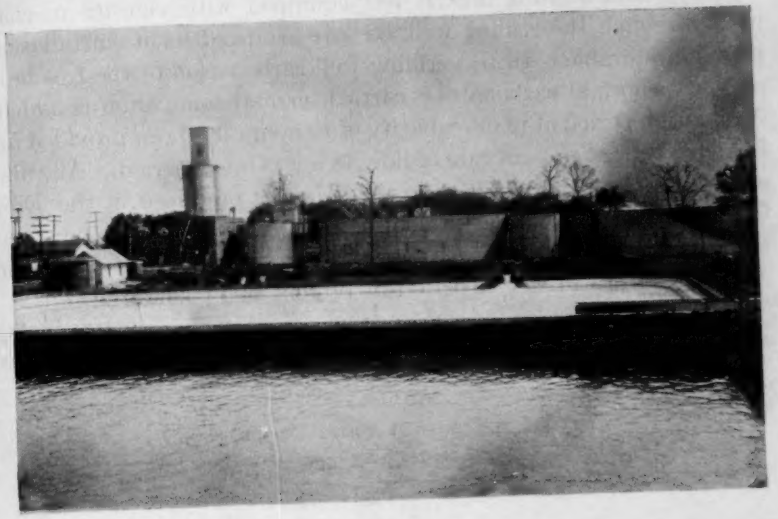

FIG. 1. GENERAL VIEW OF PLANT

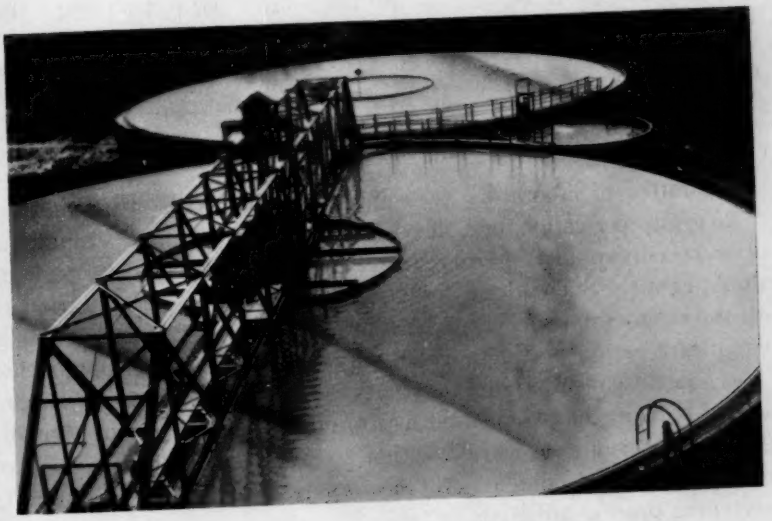

FIG. 2. CLARIFIER AND SETTLING TANKS

12 foot downward, and then outward, finally overflowing into the launder at the periphery of the tank. The sludge is removed from

this clarifier by means of Dorr sludge pumps and contains between 65 and 75 per cent moisture.

The second settling tank is not equipped with clarifier mechanism, although the stilling well, etc. are arranged for its installation if found desirable. In this stilling well carbonation of the free lime present to normal carbonates is carried on, and some alum is added. A retention period at plant capacity of 19 hours has been provided for in each basin; at present rate of flow 48 hours is the period. An effluent having a turbidity of 2 p.p.m. or less is produced in the Dorr Clarifier, with a final plant effluent turbidity of less than 1 p.p.m.

Final carbonation is carried out in a carbonating basin, 26 feet in diameter with a retention period at present of $1\frac{3}{4}$ hours.

Chemicals are unloaded by vacuum, an Airveyor system being used.

TABLE 1

Typical well water analyses, Marion, Ohio

Results in p.p.m.

	WELL 2	WELL 4	WELL 15	WELL 17	WELL 25	WELL 20
Alkalinity (as $CaCO_3$)	312	318	306	275	306	240
Non-carbonate hardness	736	529	392	507	294	452
Total hardness	1,048	847	698	782	600	692
Magnesium	56	47	45	49	38	46
Free CO_2	72	67	57	50	35	45

OPERATION

A number of laboratory tests indicated that with a lime dosage of 25 grains per gallon, or a theoretical excess of 6 grains, a minimum of soda ash would be required and a maximum hardness removal would result. Such a lime dosage insured complete precipitation of all the magnesium present, and eliminated some of the troublesome complex reaction products, commonly resulting in high alkalinities. This lime dose resulted in a causticity or free lime content of 30 p.p.m. and this figure has been used as a guide in the treatment control. The soda ash dose is varied with the raw water hardness to give any desired plant effluent. Typical analyses of various steps in the softening process are given in table 2.

Average operating results for various months are given in tables 3 and 4.

Some operating difficulty has been experienced in preventing the clogging of the chemical feed lines. Sufficient diluting water has solved this problem so well, however, that the present lime line has not been cleaned for 8 months, and the cleaning time for the soda ash line has been extended from weekly periods to periods of 30 days.

Discussion of the proper place to carbonate to the normal carbonate stage led to an experimental installation of a carbonating grid at the influent to the Dorr Clarifier. This location was considered as practically identical with carbonation directly in the mixing basin effluent. The results of this experiment were quite unsatisfactory as low alkalinities could not be obtained and very poor settling resulted. An examination of table 4 shows that higher causticities were apparently carried in the mixing chamber during the time of making this test

TABLE 2

Typical analyses at various steps in softening process

Results in p.p.m.

	RAW	MIXED	CLARIFIED	SETTLED AFTER FIRST CARBONATION	CARBONATED
Total alkalinity	303	61	69	35	33
Phenol alkalinity	0	50	59	19	6
Causticity	0	39	49	3	0
Non-carbonate hardness	438	168	109	111	106
Total hardness	741	229	178	146	139

and that insufficient CO_2 gas was added. Plotting the daily results, however, indicates that the poor results must have been due to some obstruction to the reaction between the CO_2 and the free lime, as at various times very high causticities have not resulted in high effluent alkalinities when the first carbonation was carried on in partially clarified water. Carbonating at this point also resulted in the formation of very small floc particles which would not settle readily. The turbidity of the plant effluent was increased from one or less to 10 or 15 p.p.m.

An inspection of table 3 shows that a decrease in the pounds of soda ash per m.g. had occurred. This is probably due to increased time of retention in the mixing basins. A change in the rate of flow through the basins is apparently directly reflected in the soda ash required. These results are summarized in table 6.

This decrease in soda ash required represents a saving of approximately $4.00 per million gallons, or an additional removal of approximately 30 p.p.m. hardness (non-carbonate) with the same chemical dose formerly used.

TABLE 3

Average operating results, Marion, Ohio

	GALLONS TREATED	POUNDS PER MILLION GALLONS				LIME DATA		SODA ASH
		Lime	Soda ash	Alum	Coke	Pounds per m.g. per p.p.m. alkalinity reduced	Pounds per m.g. per p.p.m. total alkalinity	Pounds per m.g. per p.p.m. non-carbonate hardness removed
	m.g.							
August	42,234	3,775	2,875	39	293	13.8	12.3	11.8
September	30,663	3,040	3,040	34	391	15.4	13.9	13.8
October	28,000	2,970	2,970	37	443	16.0	14.3	11.9
November	30,247	3,061	3,061	56	204	15.7	14.1	10.1
December	30,601	3,057	3,057	49	101	14.6	12.7	10.5
January	31,142	3,080	3,080	47	99	14.9	13.2	10.6
February	32,057	3,090	3,090	45	87	14.3	12.6	10.4
March	32,785	3,115	3,115	55	100	14.2	12.5	9.9

TABLE 4

Average operating results, Marion, Ohio

Results in p.p.m.

MONTH	RAW WATER				PLANT EFFLUENT			
	Total alkalinity	Non-carbonate hardness	Total hardness	CO_2	Total alkalinity	Phenol alkalinity	Non-carbonate hardness	Total hardness
August, 1928	306	399	705		34	5	154	188
September, 1928	304	384	688		30		164	194
October, 1928	301	406	707	29	32	7	156	188
November, 1928	297	425	722	40	38	6	141	173
December, 1928	296	414	710	37	34	6	123	161
January, 1929	297	412	709	45	34	6	122	156
February, 1929	302	426	728		35	7	128	163
March, 1929	305	427	732	87	35	6	114	149

TABLE 5

Results of experiments in applying CO_2 directly to mixing basins effluent

Results in p.p.m.

	RAW			MIXED			CLARIFIED			SETTLED			CARBONATED		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Total alkalinity	299	295	297	62	89	80	61	67	65	30	55	35	28	39	35
Phenol alkalinity				47	75	55	51	57	55	16	46	16	5	17	5
Causticity				31	61	30	41	57	45	2	37		0		
Non-carbonate hardness	423	426	424							154	165	121	155	140	121
Total hardness	722	721	721							184		156	183	179	156
CO_2	34									0	0	0			

CO_2 gas used per day in cubic feet

10 DAYS BEFORE TEST	7 DAYS DURING TEST	10 DAYS AFTER TEST
14,240	18,200	18,240

Coke used in pounds per day

280	200	200

TABLE 6

Effect on soda ash dosage of decreasing rate of flow through mixing chambers (lime and soda ash dosage practically constant)

Results in p.p.m.

	RAW WATER		PLANT EFFLUENT	
	(a)*	(b)*	(a)*	(b)*
Average alkalinity	302	298	29	35
Phenol alkalinity	0	0	5	6
Non-carbonate hardness	421	421	163	122
Total hardness	723	719	192	157
CO_2	31	36	0	0

	(a)	(b)
Pounds of lime per million gallons per p.p.m. reduction in alkalinity	16.1	14.8
Pounds of soda ash per million gallons per p.p.m. reduction in non-carbonate hardness	12.0	10.7
Average rate of treatment, thousands gallons per hour	60,000	52,000
Retention period in mixing chambers	4 hrs. 10 min.	4 hrs. 50 min.

*(a) Average 15 days before decreasing rate. (b) Average 15 days after decreasing rate.

Double carbonation has resulted in alkalinities averaging 30 to 35 p.p.m., whereas in laboratory test without double carbonation, alkalinities below 65 p.p.m. could not be produced. Double carbonation has then resulted in a removal of 30 p.p.m. hardness at a cost of practically nothing, a constant amount of coke being used, regardless of whether single or double carbonation is carried on. If it is assumed, however, that one-half of the total coke used is necessary to produce this result, costs would be as shown in table 7.

TABLE 7

Cost of removing hardness by double carbonation

MONTH	TOTAL COKE	ASSUMED COST PER M.G. OF CARBONATION	COST PER P.P.M. HARDNESS REMOVED	TOTAL AVERAGE COST FOR REMOVING ONE P.P.M. HARDNESS (WITH LIME AND SODA ASH)
	pounds per m.g.			
August	293	$0.51	$0.014	
September	391	0.68	0.019	
October	443	0.77	0.021	
November	204	0.70	0.021	
December	101	0.35	0.010	
January	99	0.34	0.010	
February	87	0.31	0.009	
March	100	0.35	0.010	
Average				$0.097

Sludge disposal is rapidly becoming a serious problem and considerable study is being given it. No practical solution, however, has as yet been found.

The temperature changes taking place through the plant may be of interest. The well water has a constant year around temperature of 54°F. During the winter the water in the basins gets as low as 37°. In the summer variations exist as follows:

Temperature changes in plant at Marion, Ohio

ATMOSPHERE	WELL WATER	MIXING CHAMBERS	CLEAR WELL	TAP	DATE
degrees	°F.	°F.	°F.	°F.	
81	54	58	63		July 5, 1928
	52		63	68	July 20, 1928

The Marion Water Company softening plant was designed by C. P. Hoover of Columbus and was constructed under the direction of George Whysall, Manager of the Marion Water Company, under immediate supervision of Charles Whysall, now chemist in charge. Thanks are due these gentlemen for permission to publish the data given in this paper.

FACTORS OF SAFETY IN THE OPERATION OF WATER WORKS[1]

By Earle L. Waterman[2]

During the past summer the writer happened to be working in a city of 125,000 population when a series of accidental breakdowns practically shut off the water supply of the city for a period of 35 hours. Fortunately the misfortune was passed without serious damage to life or property—the greatest damage was done to the relations between the public and the water department. This incident seems worthy of comment in greater detail and is provoking of thought on the matter of factors of safety in the operation of water works.

It is a generally accepted fact that our municipal water works are the most important of the public utilities. The public demands that the water works should function at all times to the end that an adequate supply of water that is safe from a health standpoint, and potable from the aesthetic standpoint be furnished. In addition, the supply should be ample in volume and under sufficient pressure to furnish reasonable fire protection at all points reached by the system. Failure to meet any of these essential requirements brings instant condemnation of those in charge of the operation of the water works plant. These three requirements, then, may be taken as the standards which must be met and the factors of safety in the operation of the system may be measured by the degree to which the system is able to meet these requirements under the most severe conditions which may occur.

Since we are considering the water works system from the operating rather than from the design side, let us assume that the system has been planned and constructed in such a way that it is sufficiently flexible and has the necessary reserve to meet requirements of health, potability, quantity, and pressure under the most unfavorable circumstances. All reasonable precautions have been taken to insure

[1] Presented before the Missouri Valley Section meeting, November 7, 1929.

[2] Professor of Sanitary Engineering, University of Iowa, Iowa City, Ia.

the safety of the source of supply, ample capacity provided by the supply conduits, reserve pumping and purification equipment have been installed, the distribution system has been carefully planned with proper sizes of pipe and carefully chosen location of valves and hydrants, and a reserve storage is sufficient to supply the system over periods of maximum demand plus the time that may be required to make repairs should a break in the supply line occur. The designing engineer has done his part and it is then the operator's job to keep the system in proper operating condition. With the most carefully planned system the responsibility of the water works superintendent is a tremendous one and the satisfactory discharge of this responsibility involves continual vigilance and a constant state of preparedness to meet emergencies.

There are two ways in which breakdowns in the water system may endanger public health—furnishing an unsafe water or no water. A supply of unsafe water may result when the purification equipment fails to meet unusual conditions or when the operator fails to use such equipment intelligently. Unusual conditions, inadequate equipment, and faulty operation all played some part in the cause of the typhoid fever epidemic in a section of Chicago in 1923 (1). In some instances contamination may occur after the water has left the treatment plant. This was held to be the cause of an epidemic of typhoid fever in Albany, N. Y. in April, 1924 (2).

At that time a 48-inch supply line carried water by gravity flow from the Albany filtration plant to the main pumping station. This line was 7,913 feet long and was laid in the bed of the old Erie Canal. It was claimed that the pollution which caused the typhoid fever epidemic was caused by leakage through cracks in this supply line. About 80 suits for damages against the City of Albany were brought as a result of this epidemic. A few months ago the Appellate Division of the Supreme Court of New York State unanimously affirmed a jury decision rendered in the State Supreme Court in November, 1926, which gave damages of $2000 to a minor and $1000 to his father on a claim that the minor contracted typhoid fever from the public water supply of Albany in April, 1924. The following is an extract from the decision:

"On nearly every day from April 7 to 23, colon bacilli were found in increasing numbers, indicating some definite source of pollution not eliminated by filtration. About this time there was a sudden increase in gastro-intestinal diseases in the city. The officials in charge of the water department had notice of the

defective condition of the conduit, the sudden pollution of the water, and the outbreak of diseases traceable to impure water, but the warnings were ignored. It was a time for prompt and decisive action. There were two possible sources of contamination—one by impure water passing the filters into the well, the other by introduction of polluted water into the conduit. The exercise of vigilance would have led to the discovery of the dangerous condition, and reasonable diligence would have provided the remedy. It was possible, by greater chlorination before the water went into the clear well, to eliminate all dangerous bacilli which passed the filter; and there was a chlorination plant at the Quackenbush Street pumping station which would have removed the new pollution occurring in the conduit, but this was not put in use, at least during the first ten days in April. Common prudence would have suggested a notice to citizens that the water had become polluted and a recommendation that all water intended for human consumption should be boiled. But no preventive measures were taken until an epidemic had broken out."

This decision leaves little doubt concerning the responsibility of the water works operator in matters of health as affected by the water supply.

Failure of the public water works system to furnish a potable water or perhaps, in the event of a breakdown, to furnish no water may be the cause of epidemics of water borne disease since in either case the consumer will use other sources of supply which may not be safe. This is an indirect responsibility, but nevertheless a real one and factors of safety should prevent the occurrence of either contingency.

Second only to the requirement of a safe water is that of furnishing an ample supply for fire protection purposes. The importance of providing certain factors of safety in the water works system to insure reliability of its functioning for fire defense is emphasized in the Standard Grading Schedule of the National Board of Fire Underwriters. These regulations are published in an appendix of the Manual of American Water Works Practice and deserve the careful consideration of every water works superintendent. It is not sufficient to provide for emergencies with reserve equipment. More important is vigilance in keeping all parts of the system in excellent operating condition. Reserve equipment that will not function, valves that cannot be opened, hydrants that will not work are worse than none at all when they are needed. If you do not have them the responsibility is not yours, but if you do have them and cannot use them because of neglect, you are justly subjected to public indignation. The incident mentioned at the beginning of this paper so well illustrates the possibilities of disaster and the need of factors of safety in the operation of water works systems that the writer ventures to

give a more detailed account of it. The facts as stated are not obtained from an engineering investigation, but were obtained from press accounts which so far as the writer is aware, have not been questioned.

The city of Albany, N. Y., obtains its present water supply from the Hudson River. After passing through a slow sand filtration plant the water is pumped through a 36-inch cast iron supply line to the main pumping station where it is given such additional pressure as is needed for distribution. Pumps at the filtration plant and the 36-inch supply line have been built since the typhoid fever epidemic mentioned earlier in this paper. The old 48-inch supply line was repaired and put in condition to operate as a pressure emergency line. The distribution system of the city is divided into two parts—high pressure serving most of the residential area and low pressure serving the commercial and industrial districts in the lower areas adjacent to the river. Two distributing reservoirs provide reserve storage and regulate pressures, Prospect Reservoir with a storage capacity of 7,000,000 gallons is a part of the high service system; Bleecker Reservoir with a storage capacity of 33,000,000 gallons serves the low service system.

Prospect Reservoir was drawn down to lower the pressure, and the 36-inch supply line closed and drained in order to make a connection between the reservoir supply lines at the pumping station. When water was again turned into the 36-inch supply a break occurred in a section of the pipe. This line was shut off at the filtration plant pumping station and an attempt made to put the 48-inch emergency line into service. The valve at the pumping station which controlled this line broke. Thus Prospect Reservoir on the high service line was only partially filled when both supply lines between the filtration plant and the city were out of service. A second auxiliary line from Van Rensselaer Lake was put into service, but broke in short order. Within 12 hours 80 percent of the area within the city was without water and the pressure was dropping fast in the low service zone.

After 12 hours the broken valve in the 48-inch main was partially opened and pumping was done for four hours at moderate pressure. The pumps were then shut down to permit the removal of the disc from the broken valve. Before this could be accomplished it was decided to resume pumping in an attempt to get water to the high service district. It was then discovered that the motor which operates the pump on the 48-inch line was out of service. Steam

pumps which had not been in service for many years were started. One of these developed hot bearings and had to be shut down, the other pump continued pumping into the 48-inch line.

Meanwhile the broken section on the 36-inch line was removed and a new section installed 33 hours after the original break. Water began coming through 35 hours after the original break. This break in the water service occurred during one of the most prolonged droughts in recent years. Fortunately no serious fires occurred during the period.

The reaction of the public to the situation was expressed by an editorial in one of the Albany papers, The Knickerbocker Press under date of August 2, 1929, entitled "Intolerable." The following extracts have been taken from the editorial:

"Stern indignation will temper public opinion in Albany in respect to the water situation which has caused a serious menace to the health and well being of the community in addition to inflicting incalculable harm to the city's reputation and great property loss. In such circumstances words seem futile and they will not here be multiplied. The whole distressing thing can be summed up in one word—intolerable.

* * * *

"In every enterprise, in war or in peace, the first consideration is water. Build a factory, establish a home, or pitch a tent in the woods, a prime factor, indeed the chief factor, is water. And here we are, a modern city, of great public buildings, mammoth hotels representing millions in investment and depending upon public good will and established reputation, a population of 125,000 persons, and the water supply reduced to the vanishing point. Intolerable.

"Accidents will happen, certainly. But a prudent, wise, and responsible city management will exercise an almost limitless preparedness to cope with the possible emergency. In this case dependence was placed on an engineering contrivance a century old. Intolerable.

"The one thing that can be salvaged from the total of loss is the warning. It writes itself in letters large and clear. 'Never again.' "

Prudent, wise and responsible water works operators will exercise all possible diligence to maintain and, if possible, increase the factor of safety in their water works system.

REFERENCES

(1) Eng. News-Record, Vol. 92, page 116.
(2) Eng. News-Record, Vol. 101, page 221.

RED WATER TROUBLE AND THE REMEDY AT WEST PALM BEACH[1]

By L. O. Williams[2]

The new plant of the West Palm Beach Water Company was officially put in service January 1, 1927.

The plant was designed specifically for handling the type of water available at West Palm Beach and therefore has incorporated in it several features that are of interest from the standpoint of water treatment.

The raw water is taken from Clear Lake and Lake Mangonia. These lakes are filled strictly by surface drainage and as a consequence the water has a high color combined with a low alkalinity. The raw water color for the last fourteen months has averaged 110 parts per million, while the alkalinity has averaged 38 parts per million. In order to remove this color an alum dosage varying between 475 and 525 pounds per million gallons is necessary. During periods of high water when the color is high and the alkalinity low the addition of five per cent well water has been found necessary. This adds from 5 to 7 parts per million alkalinity depending upon the characteristics of the well.

An alum dosage of 500 pounds per million gallons in the raw water liberates approximately 24 parts per million carbon dioxide. In order to get rid of this excess the water is sprayed before being allowed to coagulate. This first aeration releases approximately 16 parts per million of carbon dioxide and after filtration the water is sprayed a second time which reduces the carbon dioxide to approximately 5 parts per million.

From 1925 to the spring of 1929 the plant delivered to the consumer a water having carbon dioxide content varying between 2 and 6 parts per million with a pH between 6.2 and 6.8. Although this amount may seem small, it was sufficient to cause severe corrosion in the distribution system. The presence of 9 parts per million of dis-

[1] Presented before the Florida Section meeting, April 10, 1930.

[2] Chemist, West Palm Beach Water Company, West Palm Beach, Fla.

solved oxygen rendered this carbon dioxide highly aggressive and over a period of several years our distribution system suffered heavily. Red water complaints were received occasionally, but not in sufficient numbers to cause alarm. Samples of pipe revealed that certain sections of the distribution system were in very bad condition. In fact to look at one of the samples made one wonder how it was possible for a clear water to be delivered through such pipe. Yet such was the case. The red water complaints were comparatively few.

On January 1, 1929, it was decided to put out an effluent having a maximum carbon dioxide content of 4 parts per million. In order to do this an old dry feed, lime machine, which we had on hand was moved into the chlorine house and connected up so that lime solution could be added to the filter effluent. A lime rate of 20 pounds per million gallons was indicated. This dosage was established and maintained, more or less on through the summer up into December, 1929. This rate was changed at intervals during the summer, depending upon the characteristics of the water, the object being to maintain a pH of between 7.2 and 7.5.

The lime machine which we were using was very inaccurate the way it was used, and we had a great deal of trouble maintaining a constant rate of feed. Some days the filtered water would have a pH well above 8.5 and on other days would drop to 7.0. On one occasion the lime for a full 24 hour shift was put in in less than one hour.

With the advent of the rainy season last year, that is, in August and September, our lake rose to an elevation of 17.64 feet with a corresponding drop in alkalinity to 21 parts per million. During the summer our raw water alkalinity had varied between 90 and 35 parts per million depending upon its elevation. As soon as this last change came about our red water troubles started. Just before they started the lime was raised to a point where we should be able to maintain a pH of between 7.5 and 8.0. Our actual pH, however, ranged between 6.7 and 9.0 due to the fact that we were attempting to feed the lime through this old machine with no accurate means of checking the amount fed. This oscillating dosage was kept up for two months and during that period, November and December, we received over 90 complaints of red water. The ice plants in particular were complaining.

It was soon apparent that something had to be done to relieve the

situation. After careful investigation the following conditions were accepted as being the causes of our difficulty.

1. Certain sections of the distribution system badly corroded.
2. Presence of aggressive carbon dioxide.
3. The coating of rust existing in the mains was in the forms of ferrous carbonate, ferric hydroxide and ferric oxide with traces of aluminum hydroxide, which formed a soft mass easily dislodged by variations in rates of flow of the water.
4. The slight protective coating formed during periods of high alkalinity, which exists for two or three months during the summer, was re-dissolved when alkalinity drops, leaving the occluded iron in suspension in the water.
5. Lack of systematic flushing.
6. High dissolved oxygen content.
7. Unfortunate circumstance of having but few customers on certain long mains which retarded proper circulation.

The fact that as soon as the alkalinity dropped below a certain point, red water resulted, it was decided that the quickest and surest way to relieve the situation was to prescribe a lime dosage that would give an excess of carbonate alkalinity which would allow a deposit of calcium carbonate to form on the pipe. This would give a relatively hard surface that would not be easily disturbed by the variations in rate of flow of the water.

A test using iron filings was made to determine approximately at what pH the water was least corrosive. Physical examinations were made of each sample after 24 hours contact. The results showed that a dosage of 0.5 grain per gallon of hydrated lime rendered the water non corrosive. However, it was considered advisable to raise the dosage considerably above this amount to start with because of the fact that certain sections where most of the complaints were originating were known to be in bad condition and it was desirable to retard the red water in these sections as quickly as possible.

Accordingly a lime dosage was set which would put the calcium carbonate just on the point of precipitation. This meant a dosage of 0.71 grain per gallon which gave a pH in the finished water of 9.4.

In order to insure reasonable accuracy, a scale was mounted next to the lime machine and the amount of lime corresponding to the rate of filtering was weighed out every hour and put in the hopper. This system meant that the operator had to forecast the next hour's

pumpage and calculate the amount of lime required for that hour. This was not such a hardship, however, as our storage reservoir is large and the rate of pumpage is not subject to rapid changes.

Since this system of feeding the lime was adopted our red water troubles have practically disappeared. By using the method of weighing out the lime every hour, we have been able to keep our pH practically constant. This system was started January 1. Coincident with this a general flushing was given the entire system to clean out as much of the existing loose rust as possible. During the month of January only 12 complaints were received, and most of these were from houses that had just been opened or from sections where work was being done on the distribution system.

The lime rate of 0.71 grain per gallon was continued for two weeks and then dropped to 0.59 grain per gallon. This reduced the pH to 9.2. This dosage was further reduced to 0.50 at the end of two weeks which gave a pH varying between 8.9 and 9.0. This dosage was carried until the middle of February when it was again reduced to 0.33 grain per gallon. This brought the pH down to between 8.1 and 8.3 which was below the equilibrium point and gave a slight excess of carbon dioxide. Then our red water returned to pay us a short visit. Nine complaints were received in one day. The significant thing is that it was five days after the dosage was dropped before we received any complaints and then they all came at once. Although nine complaints were received on one day, forty eight hours after the rate of feeding was raised to 0.58 grain per gallon they practically disappeared. Judging from what happened, it would seem that the coating formed on the pipe was gradually dissolved by the slight excess of carbon dioxide and as soon as the coating was gone the water began to dislodge the rust. Then as soon as the excess calcium carbonate was re-established the coating began to reform.

Sections of pipe taken from the distribution system already show a deposit of calcium carbonate over the coating of rust and imbedded in it. The entire surface has not been covered, but the existing rust scale is considerably harder and more resistant to disturbance than the former soft mass.

The character of the water that we are now delivering to the consumer is as follows:

	p. p. m.
Alkalinity	18
Carbonate	10
Carbon dioxide	0
pH	9.2
Color	10
Chlorides	23
Hardness	52
Non-carbonate hardness	34
Carbonate hardness	18
Total iron	0.15
Sulphates	31

The use of lime in the proportion that we are now feeding increases the hardness about ten parts per million. It is felt that this is no disadvantage because, even though we do increase the hardness to 54 or 55 parts per million, the hardness during the spring and summer increases to nearly 90 parts per million due to the fact that the lake level is low. The addition of lime during periods of low alkalinity, therefore, acts as a balancing agent, decreasing the difference between the limits of hardness which we experience over a year's time. The lime dosage, we hope, can be materially reduced in the summer months when the filtered effluent runs between 20 and 40 parts per million alkalinity without the addition of lime.

A COMPARISON OF THE PHYSICAL PROPERTIES OF VARIOUS KINDS OF CAST IRON PIPE[1]

By F. N. Menefee[2] and A. E. White[2]

These tests were run for the Water Board of the City of Detroit. In a general way, they were so conducted that the results would be comparable with a similar investigation made for them in 1927 and later published in "The Proceedings of the American Society for Testing Materials," Vol. 28, part 2, 1928. They are published herewith through the courtesy of the Water Board of the City of Detroit.

The object of this investigation was to determine the relative service merits of the following kinds of cast iron pipe in 6- and 8-inch sizes:

Trade name	*How made*
Monocast	Centrifugal, Sand lined mould
Universal[3]	Horizontal Sand Cast
McWane	Horizontal Sand Cast
Delavaud[4]	Centrifugal Cast Metal mould
U. S. P. Company[4]	Vertically Sand Cast
French[5]	Old Method Vertically Cast

The present report presents, first, the central findings of the investigation, and then, following some preliminary considerations, describes in detail the physical and chemical tests made on the various kinds of pipe listed above.

FINDINGS

On the basis of the data derived from the physical tests to determine the respective characteristics of Delavaud, McWane, Universal,

[1] Project Number 633 for The Water Board of City of Detroit, March 1, 1930.

[2] Department of Engineering Research, University of Michigan, Ann Arbor, Mich.

[3] Eight-inch Universal pipe contributed by Central Foundry Company.

[4] All data except impact, radial compression, chemical, and metallurgical analysis taken from previous test published in A. S. T. M., Vol. 28, Part II, 1928.

[5] Contributed by City of Pontiac, Michigan.

American Sand Cast, Monocast, and French pipe, the following respective ratings for the 6- and 8-inch pipe are given. The method of obtaining these ratings is given on pages 830 to 834 and is set forth in tables 22 and 23. Before considering these ratings, the authors desire to point out that all of the pipe possessed such physicharacteristics that they would pass published specifications for the class of pipe to which they belong.

The American Sand Cast and the French pipe are representative of the older practice in making pipe where the unit strengths are less, but the dimensions greater. The American Sand Cast and probably the French pipe were made to meet the American Water Works Association specifications for Class B pipe which permits internal pressures up to 86 pounds per square inch, and is supposed to have a tensile strength of 20,000 pounds per square inch.

The manufacturers of Monocast, Universal, McWane, and Delavaud are pioneering into the field of higher unit strengthens with reduction in thickness and weight. The pipe tested under the above names is known as Class 150, meaning that it may be used up to 150 pounds per square inch. But in order to use this higher working pressure the factor of safety against bursting is reduced. This factor of safety of both the new and the old pipe is about the same with the same internal pressure.

The rank of 100 in the table of final ratings given below means that the pipe in question meets the published specifications under which it is sold. The additional amounts are the points gained in the various tests and totaled in tables 22 and 23.

Table of final ratings

Six-inch pipe		*Eight-inch pipe*	
Delavaud	110.0	Delavaud	110.0
McWane	108.5	Monocast	109.5
Universal	107.7	Universal	108.9
American Sand cast	106.8	French	107.0
Monocast	105.7	McWane	106.7
French	104.5	American Sand Cast	105.4

In the case of both the 6- and 8-inch pipe, the Delavaud shows the highest general characteristics. In all cases, the American Sand Cast and French pipe are toward the bottom, if not at the bottom, of the rating. It is quite evident, therefore, that vertically cast sand cast pipe, which is the manner in which American Sand Cast and French

pipe is made, does not show the same general high physical characteristics as does the pipe made in accordance with recent improvements, such as is the case of the Delavaud, McWane, Universal, and Monocast Pipe.

It is recognized that a number of the pipes take a different rating for the 8- and the 6-inch size. This is due in part to the limited number of samples of pipes inspected, in part to metallurgical differences, in part to variations in dimensions of the molds, and also in part to the different minimum thicknesses which the respective designing engineers for the companies specify for the respective pipes in question. As an instance of the metallurgical differences which may arise table 2 shows Monocast third place in tension for 6-inch pipe, but in first place in 8-inch pipe (see also figure 2). Since tensile resistance is such an important factor in the method of rating herein chosen the wide difference in tensile resistance between 6- and 8-inch Monocast is reflected at once in the final rating table.

PRELIMINARY CONSIDERATIONS

Before proceeding with an account of the various tests given the samples of pipe studied, it may be well to recall the history of the present investigation, and to review the distinguishing characteristics of these different samples, as is explained in the different processes of manufacture.

GENERAL HISTORY OF PRESENT INVESTIGATIONS

The tests were preceded by a series of conferences between the Department of Engineering Research and F. H. Stephenson, Engineer of Water System, Department of Water Supply, City of Detroit, and one conference with Jas. T. MacKenzie of the American Cast Iron Pipe Company of Birmingham, Alabama, and Mr. Clark of the United States Pipe and Foundry Company, Burlington, New Jersey. Through an inadvertance no representative of the McWane Cast Iron Pipe Company of Birmingham, Alabama, was present at these conferences. At a later date, however, and before all of the tests were finished, A. W. Claussen of the McWane Company, made us a very pleasant and instructive visit.

At these preliminary conferences it was decided that the following qualities of the pipe should be investigated:

Tensile Resistance
Radial Compression, Resistance and Deflection
Transverse Bending Resistance and Deflection
Impact Resistance
Variation in Thickness
Chemical
Metallographic

Other qualities, such as weight, inside smoothness, flaws, and difficulty in cutting, which might be noticed or easily recorded during the conduct of the test were also to be investigated. This report does not go into the merits of length, special ends, or calking devices.

Test specimens. In the present study all test specimens except those for impact tests were of the same dimensions as those used in the previous investigation. The different specimens are diagrammed and shown in figures 10 and 11. The impact specimens used in the previous tests were more numerous but the results obtained from them were not any more conclusive than those obtained from the present specimens. At that time it was known that impact testing was not as satisfactory as was wanted, nor was it possible to correlate tests made on different types of machines and different types of specimens. It was felt, however, that with care, consistently comparative results could be obtained on the various kinds of pipes if the necessary care could be exercised in subjecting the specimens to like conditions. At the time of the former study various impact tests were run using Olsen, Izod, Charpy, and Baby Olsen machines on both notched and no-notch specimens. While we believe we determined the *quality* of the various types of pipe material in resistance to impact, there still existed the question of whether or not the notch had cut through the material at the surface and influenced the results. There are no standard methods for converting data collected from specimens all cut to the same size into impact resistance data of actual pipe material of different dimensions. We could see the possibility of a pipe proving to have a low impact quality, when judged by relative tests on a series of standard size impact specimens, but which would have a relatively higher resistance to impact in service due to its greater thickness.

From tension-test data unit strengths may be derived for the material and from this the total strength of any area can be computed, but this cannot be done with impact data. Thus the impact test on some standard dimension specimen loses its value in cast-iron pipe testing.

We therefore decided to attempt to use a specimen of a pre-determined standard width and of the full thickness of the pipe without a notch. This required considerable experimentation and revamping of the grips of the impact machine as well as reducing the kinetic energy of the pendulum from one hundred to twenty foot-pounds. In revamping the grips it was necessary to redesign the movable grip vise so that its surface moved parallel to itself instead of rotating about a fixed pivot as is the case in the machine where specimens are all of the same thickness. It became necessary also to guard against the wedging of that portion of the specimen which was broken off and against its attendant absorption of pendulum energy. After considerable experimentation we finally notched our specimens at each side as shown in figure 1a in order to localize the shock at one particular cross section and yet retain the inside and outside material.

TABLE 1

Variation in thickness of sand-cast pipe

6-INCH PIPE	8-INCH PIPE
Nominal inside diameter, 6 inches	Nominal inside diameter, 8 inches
Nominal wall thickness, 0.48 inch	Nominal wall thickness, 0.51 inch
Minimum general wall thickness allowed, 0.40 inch	Minimum general wall thickness allowed, 0.43 inch
Minimum wall thickness limited to 8 inches in any direction allowed, 0.38 inch	Minimum wall thickness limited to 8 inches in any direction allowed, 0.41 inch

These tests and a study of pipe catalogues and specifications bring out the fact that foundry practice and metallurgical standards are changing. Higher unit strengths are being sought, greater uniformity in material and dimensions are offered, and as a result of the higher unit strengths a reduction in thickness and weights for the same degree of usefulness is being attempted. This all affects previous published standards and specifications and until a satisfactory standard is again agreed upon pipe should be purchased on the basis of special comparative tests instead of on the basis of American Water Works Association specifications, as has been the procedure for many years.

As an illustration of the foregoing, table 1 of our previous report (as published in *Department of Engineering Research Reprint Series*) gave data from American Water Works Association Standard on thicknesses of 6- and 8-inch pipe with allowable variation as follows:

For pipe whose standard thickness is less than 1 inch, the thickness of metal in the body of the pipe shall not be more than 0.08 inch less than the standard thickness, and for pipe whose standard thickness is 1 inch or more, the variation shall not exceed 0.10 inch, except that, for spaces not exceeding 8 inches in length in any direction, variations from the standard thickness of 0.02 inch in excess of the allowances above given shall be permitted. For special castings of standard patterns, a variation of 50 percent greater than allowed for straight pipe shall be permitted.

These standards of thickness were based upon an acceptable unit tensile strength of 20,000 pounds per square inch and 86 pounds per square inch internal working fluid pressure. Any additional thickness was of no particular value since the minimum thickness was thought to control the bursting strength and any greater thickness merely added to the weight without adding to the usefulness of the pipe. Minimum thicknesses were carefully guarded to assure safety with the assumed internal working pressures.

In this connection it should be recalled that in our former report we said, "Attention is invited to the importance of control of wall thickness, bearing in mind that it is the minimum thickness that controls in tension, not the nominal," and that Talbot and Reichart, on Strength of Cast Iron Pipe, A. S. T. M., 1926, said, "It is worth noting that the fracture of every pipe occurred at the part of the circumference and the portion of the length that had the least thickness of wall." But in our present set of tests we find that in the majority of cases a reduction in thickness produces a higher unit tensile strength, and, while not enough to reverse the above rule, yet it would not be surprising to find an occasional exception.

In contrast with the unit strength of 20,000 pounds per square inch for Sand Cast pipe, (and probably for the foreign pipe, see figures 2 and 3 for test results) Monocast, Universal, McWane, and Delavaud pipe all attempt higher unit strength and thinner sections in order to reduce costs of raw material, handling, and freight. The following questions naturally arise:

1. What is the resultant effect on the tensile properties of the pipe as to service requirements?
2. What is the resultant effect on the resistance of the pipe to service requirements of radial compression and radial deflection?
3. What is the resultant effect on service requirements relative to linear deflection?
4. Is the impact resistance as pipe increased or decreased?
5. Is the uniformity of thickness improved by these newer methods of manufacture?

6. Do chemical analysis and metallographic examination support the findings of the physical tests which are designed to answer questions 1 to 4?

Testing machines used. The following testing machines were used in this investigation:

Tension tests—Olsen 1,000,000-pound capacity, universal, lever type.
Radial Compression—Same.
Transverse Bending—Olsen 12-inch span arbitration bar machine.
Impact—Olsen Izod type 100-foot pound capacity, modified in our own laboratory as to capacity and method of adjusting grip on specimen.

The variation in thickness was measured by micrometers, no attempt being made to remove paint or small pimples which might cause a variation of a few ten-thousandths of an inch.

Marking of pipe. From each kind or make of pipe of each diameter we had 10 specimens each 18 inches long. The pipes were marked as follows:

Monocast	$M_1, M_2 \ldots M_{10}$
Universal	$U_1, U_2 \ldots U_{10}$
French	$F_1, F_2 \ldots F_{10}$
McWane	$W_1, W_2 \ldots W_{10}$

These designations went on every pipe and specimen. The 6- and 8-inch pipes were run through on separate schedules, so that the designation 6 or 8 was not necessary. The first five pipes, M_1 to M_5, U_1 to U_5, and so on, were used for the radial compression tests. The remainder of each lot, M_6 to M_{10}, etc., were used to provide tension, impact, and transverse bending specimens. The broken parts of the pipe pieces used for radial deflection were not used in making tension, bending, and impact specimens because of the possibility of damage being done to them in the radial deflection tests. Thus in the test data and in diagrams, M_1 means a specimen from the 18-inch length of Monocast pipe number 1 out of the total 10; or F_6 means pipe length number 6 of French make; the diameter in each case is found in the caption under the diagram.

Processes of manufacture

Following is a brief account of the processes of manufacturing the various kinds of pipe studied in this investigation so far as they are known.

Monocast. Monocast pipe is made by the American Cast Iron Pipe Company of Birmingham, Alabama. They attempt to get uniformity by the centrifugal process, which consists of pouring the hot metal into a horizontal mold which is spun about its longitudinal axis thus throwing the fluid outward against the inside of a long cylinder of metal lined with sand. This lining of the metal mold can be made very uniform in thickness and produces the metallurgical effect of slow cooling and corresponding freedom from brittleness. The process produces a bell and spigot pipe in 16-foot lengths.

Universal. Universal pipe is horizontally cast in green sand molds in standard 6-foot lengths. In order to prevent uneven cooling and unequal contraction and cooling stresses the pipe is allowed to cool in the moulds until the glowing color of the mould due to its high temperature has disappeared. It has special universal joint ends and flanges.

Delavaud. In the metal-mold centrifugal process, the pipe is cast in a revolving steel cylindrical mould the interior surface of which corresponds in every detail with the exterior of the pipe to be cast. Molten iron is poured through a spout extending through to the end of the mould and as the iron begins to flow the cylinder develops two motions. One is a revolving motion by which the iron is distributed centrifugally against the inner circumference. The other is a longitudinal movement by which the mold is drawn back, permitting the end of the spout to deliver molten metal along the inner surface of the revolving mold until the spout emerges from the end at which it entered. Inasmuch as the pipe is cast in a chill mold, it must be annealed before it is ready for service.

American Sand Cast. The sand-cast process is the oldest method of manufacturing pipe. It has been in use for over 100 years. It consists in placing within iron flasks core boxes covered with hay, straw or shredded rope protected on the outside by sand and clay. These core boxes are baked before they are placed in the flasks in order to give their surface proper hardness. The iron is poured through suitable gates between the flask and the core, resulting in the formation of the pipe. After the metal has been poured into the mold, the flask is opened and the pipe is removed while quite hot.

French. As far as is known the French pipe is manufactured in essentially the same manner as is American sand cast pipe.

McWane. McWane pipe is horizontally cast in green sand molds. There are fourteen gates in a 16-foot length of pipe. The sand core

is locked in the mold and securely held in place to assure even thickness of pipe.

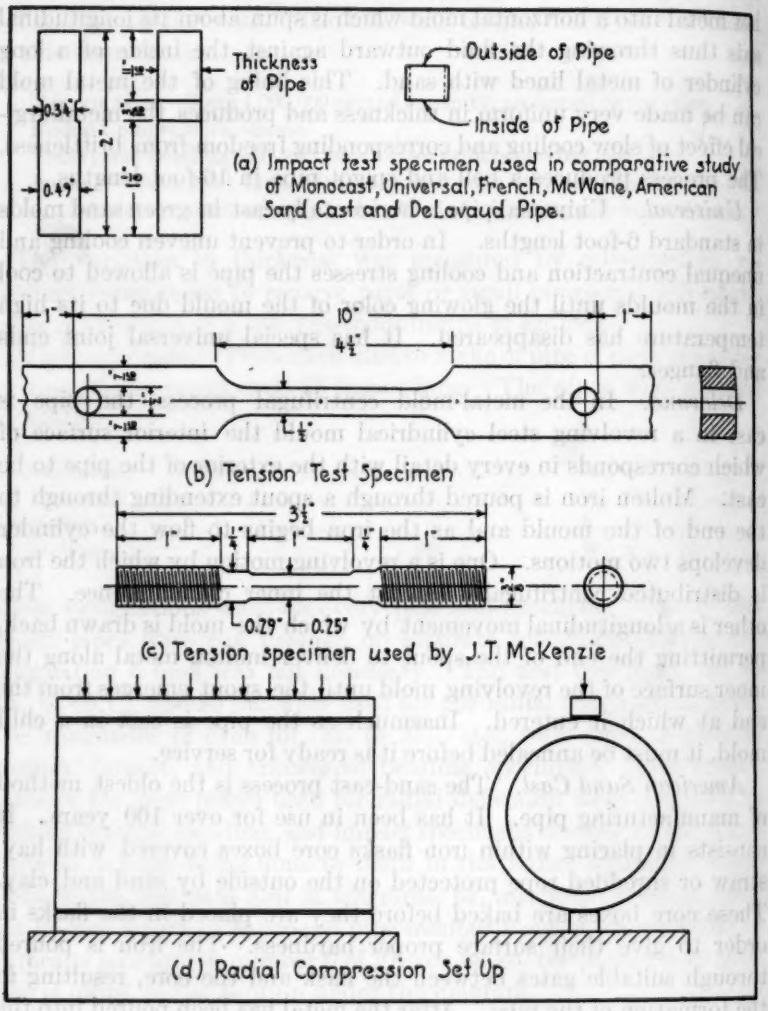

FIG. 1

PHYSICAL TESTS

The following tests were given to determine the physical properties of the samples of pipe studied:

Tensile Resistance
Radial Compression
Transverse Resistance
Impact Resistance
Variation in Thickness
Variation in Weight
Smoothness

Tensile resistance

Tensile-test specimens were of the same type as formerly used. It is admitted that they are not entirely satisfactory, but it is likewise felt that the very small circular-section specimen, figure 1c, is not representative of the material in the pipe. Figure 1b shows the one that we used.

Figure 2 shows the comparative results of the unit tensile resistances on the thin side of the four 6- and 8-inch pipes under consideration—namely, Monocast, Universal, French, and McWane—to which have been added the Delavaud and Sand Cast of our previous report. Figure 3 shows the same for the thick side of the pipe. Leaving out of consideration the Delavaud and Sand Cast, it will be noted that for the 6-inch pipe the thin side seems to run to slightly higher strengths, whereas the opposite is the case in the 8-inch. The Delavaud and Sand Cast data are brought forward from previous tests where no discrimination was made between the thick and thin side in selecting specimens.

While no attempt was made to concentrate attention on the gate portion of the McWane pipe, we purposely took some of each kind of test specimen in the line of gates and in the radial deflection tests arranged to have the element in which the gates occurred at the top or bottom in a few cases. No appreciable difference in physical qualities was discernible.

Placed in order of their relative *unit* resistances beginning with the highest, the pipes take the order given in tables 2 and 3.

In each of the tables whose data contributed to the rating in a direct way, will be found a column of points. These points were arrived at by giving six points to the most desirable pipe in the test in question and one point to the least desirable and by computing the rank of the intervening four pipes on a proportionate basis. The composite ratings of the various makes of pipe are given in tables 22 and 23 in the conclusions. But, placed in their relative order as concerns their resistance to bursting, and taking into consideration their *minimum*

thickness and their unit resistance, these pipes take the order given in table 4 and illustrated in figure 5. This tabulation is based on the minimum thickness found on any one piece of pipe, whereas table 5

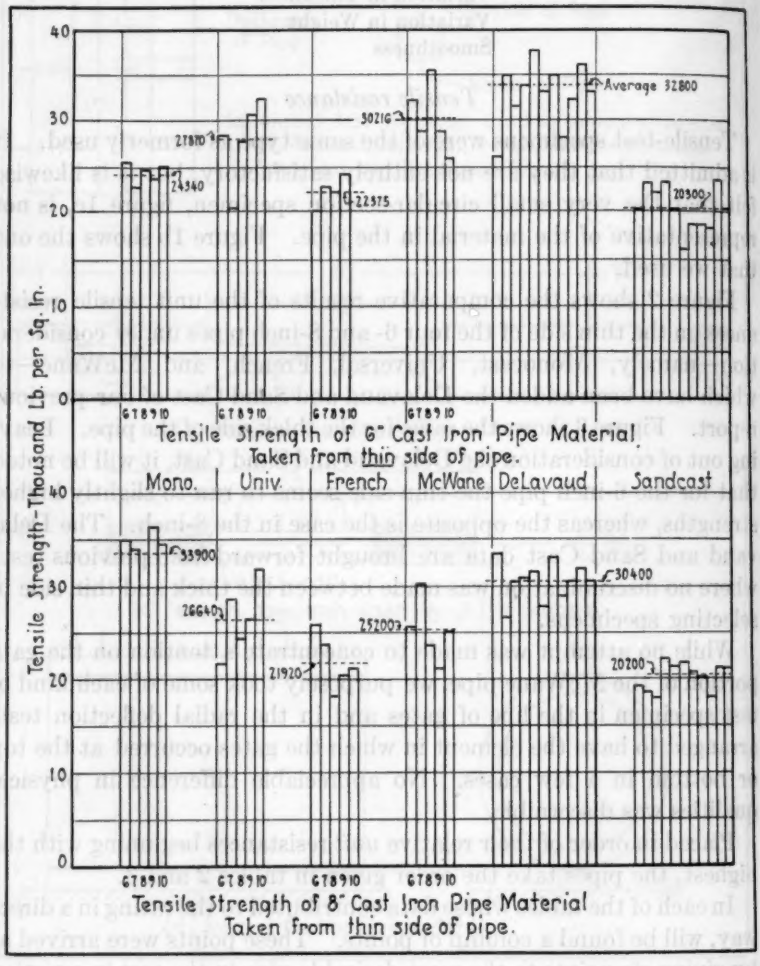

FIG. 2

expresses the relative order of resistance to bursting based on the thickness of the tensile specimen and is taken from the diagram in figure 4. In the preliminary discussions concerning the tests, J. T McKenzie, Chief Chemist, American Cast Iron Pipe Company,

Birmingham, Alabama, asked that we give him a strip of cast iron out of each pipe from immediately adjacent to the specimen we took. Mr. McKenzie wanted to turn the samples down to the shape and

TABLE 2

Six-inch pipe

	THIN SIDE		POINTS†	THICK SIDE	
1	Delavaud	32,800*	6.0	Delavaud	32,800*
2	McWane	30,216	5.0	McWane	29,494
3	Universal	27,870	4.0	Universal	24,450
4	Monocast	24,340	2.3	Monocast	23,440
5	French	22,375	1.8	American Sand Cast	20,300*
6	American Sand Cast	20,300*	1.0	French	19,920

* Data from former test.
† Points based on thin side data.

TABLE 3

Eight-inch pipe

	THIN SIDE		POINTS‡	THICK SIDE	
1	Monocast	33,900†	6.0	Monocast	32,330
2	Delavaud	30,400*	4.7	Delavaud	30,400*
3	Universal	26,640	3.3	Universal	28,920
4	McWane	25,200	2.8	McWane	26,640
5	French	21,920	1.6	French	22,970
6	American Sand Cast	20,200*	1.0	American Sand Cast	20,200*

* Data from former test.
† Admittedly higher than usual.
‡ Points based on thin side data.

TABLE 4

Pounds per square inch internal bursting pressure

6-INCH PIPE			8-INCH PIPE		
		Points			Points
Delavaud	12,068*	6.0	Delavaud	15,181*	6.0
McWane	10,227	4.4	Monocast	11,997	3.2
French	9,193	2.9	French	11,687	2.9
Universal	9,039	2.6	McWane	9,845	2.2
Sand Cast	9,022*	2.3	Universal	9,453	1.9
Monocast	7,909	1.0	Sand Cast	9,409*	1.0

* Data taken from previous report.

size of the specimen shown in figure 1c, and to test them as a check on the specimen we used.

Specimens for Mr. McKenzie were taken from the thin side of the

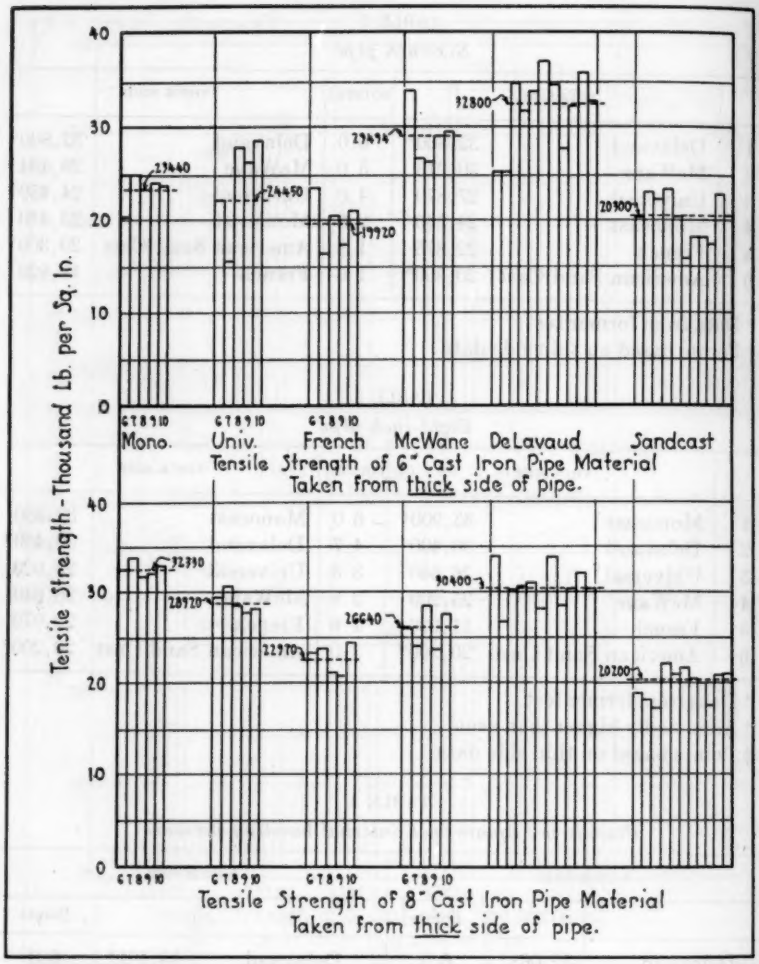

FIG. 3

pipe and immediately adjacent to our specimens shown in figure 1b. For that reason the average of any one group of tension tests by Mr. McKenzie should be reasonably close to the average in our group of specimens shown in figure 2, which is a graphic picture of the strength

of our specimens taken from the thin side of the pipe. Figure 6 is a diagram showing the relative average strengths of Monocast, Universal, French, and McWane, in which number 1 is the strength according to the McKenzie average, 2 the strength according to the average we obtained for the thin side, and 3 the average strength with our type of specimen on the thick side.

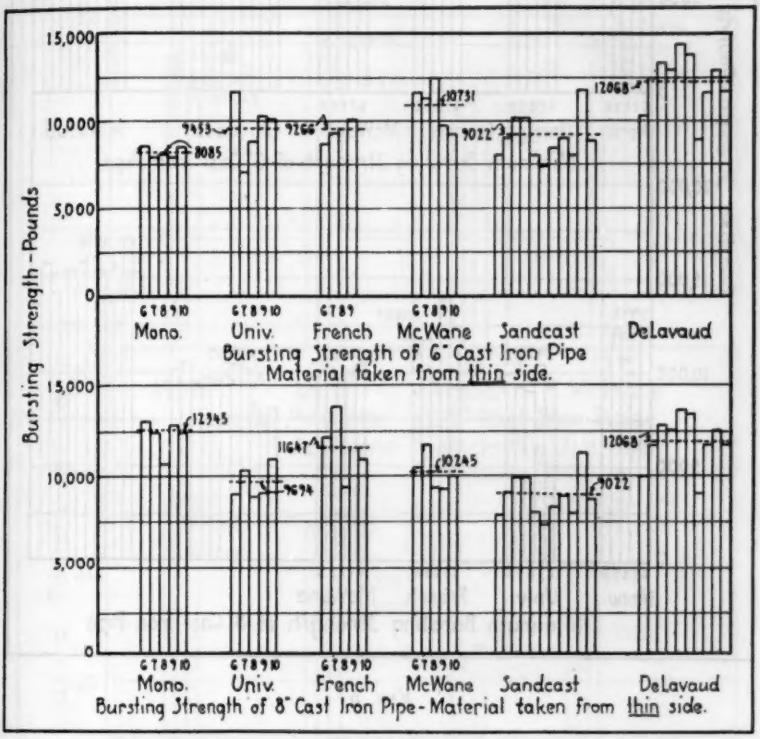

FIG. 4

Radial compression tests

The results of the radial compression tests are shown in figures 8 and 9. The diagrams show not only the results derived from Monocast, Universal, French, and McWane pipe, but also those from the Delavaud and Sand Cast. These results were taken from tests which were rerun instead of being taken from a previous test. Figure

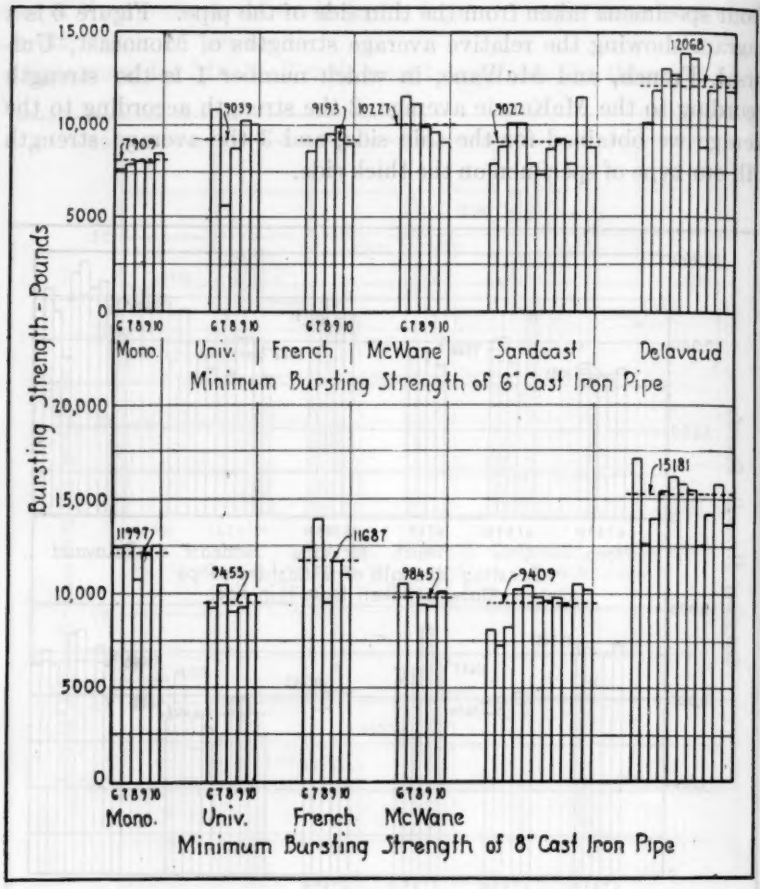

FIG. 5

TABLE 5*

Pounds per square inch internal bursting pressure

6-INCH PIPE		8-INCH PIPE	
Delavaud	12,068†	Monocast	12,345
McWane	10,731	Delavaud	12,068†
Universal	9,453	French	11,647
French	9,266	McWane	10,245
Sand Cast	9,022†	Universal	9,694
Monocast	8,085	Sand Cast	9,022†

* Not used in final rating.

† Data taken from previous report.

8 shows that the French and Sand Cast pipe in both the 6- and 8-inch sizes ran about the same and are relatively high.

Considering high resistance to crushing as a merit the relative order of quality in the pipe is expressed in table 6. As was previously

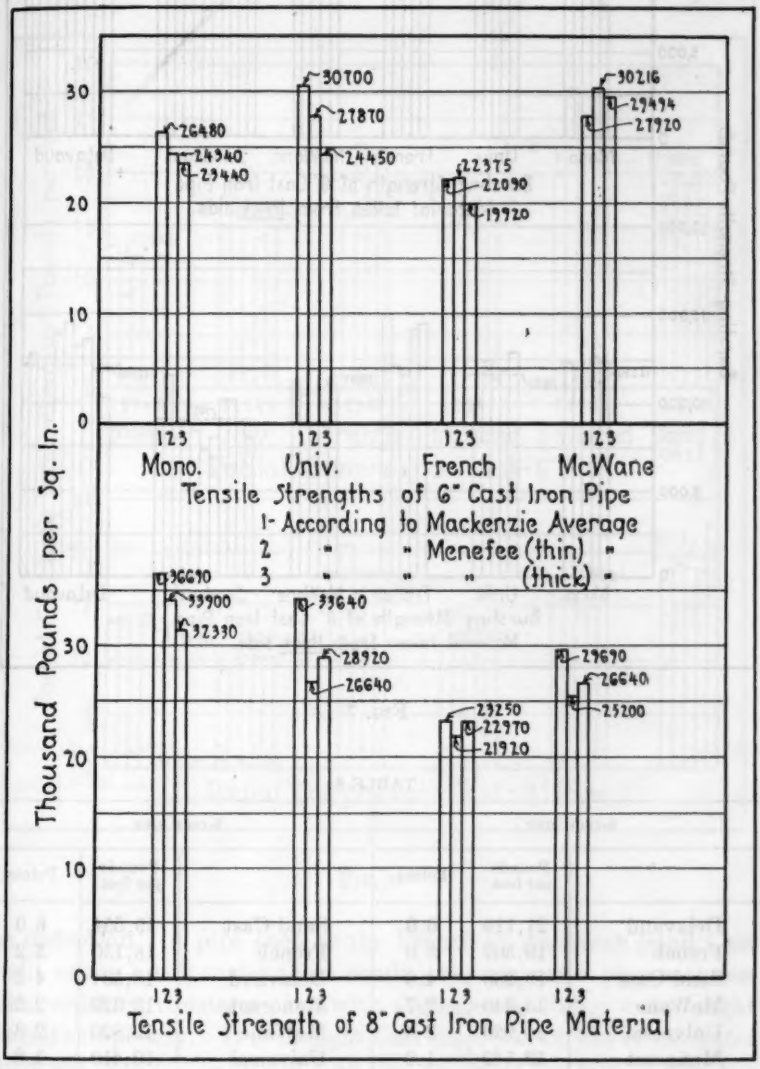

FIG. 6

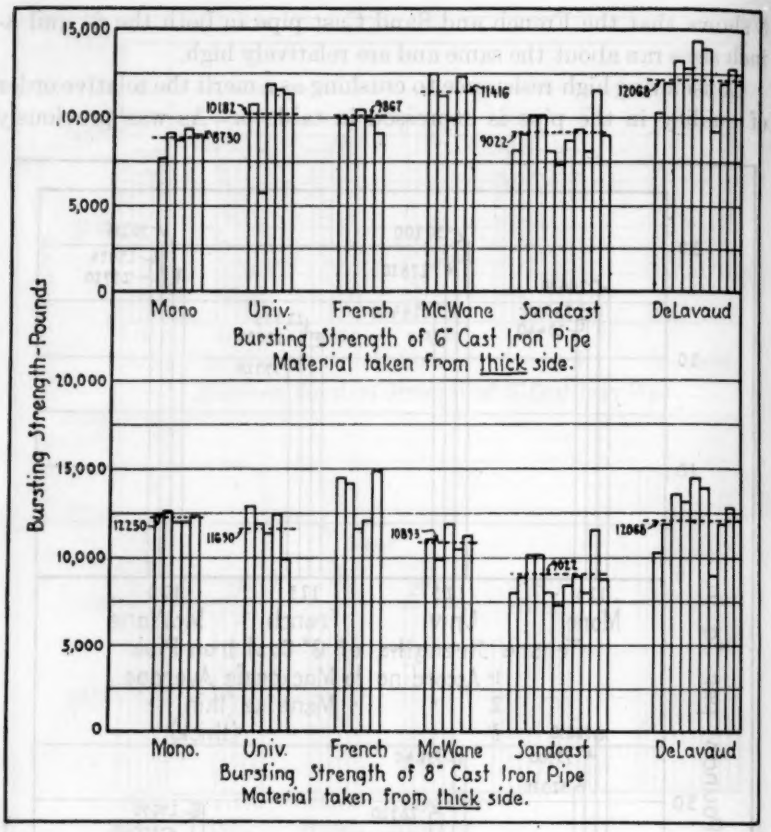

FIG. 7

TABLE 6

6-INCH PIPE			8-INCH PIPE		
	Pounds per foot	Points		Pounds per foot	Points
Delavaud	21,110	6.0	Sand Cast	19,554	6.0
French	19,502	5.0	French	18,130	5.2
Sand Cast	19,260	4.8	Delavaud	16,534	4.3
McWane	15,440	2.7	Monocast	13,320	2.5
Universal	14,920	2.4	McWane	12,820	2.3
Monocast	12,542	1.0	Universal	10,410	1.0

reported the extent to which resistance to crushing should be considered an indication of superiority where the pipe having the higher resistance to crushing has a low deflection index is questionable. There are some instances where a pipe is subject to pressure of a rather irresistible quantity, but where the pressure diminishes rapidly with

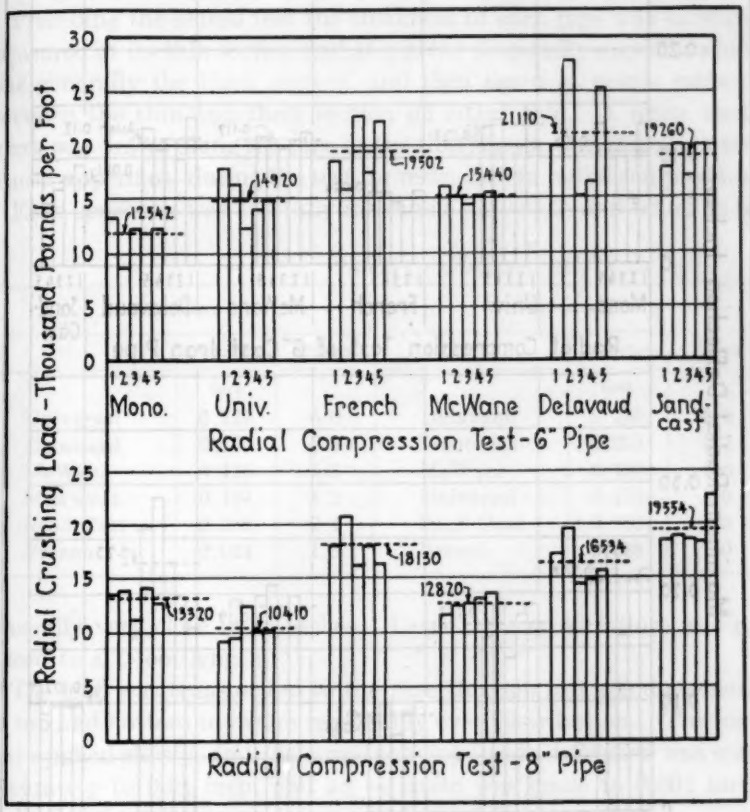

FIG. 8

the deflection. A pipe such as the French or American Sand Cast might easily break under these conditions, whereas a pipe with less radial crushing resistance, but with a greater flexibility index might not fail completely. It is thought that there will be less of the latter situations than of the former, and that probably the pipe having the greater resistance to compression should be favored in this particular

test. As stated in our former report, there are some circumstances where a yielding pipe may be helpful, and certainly some which

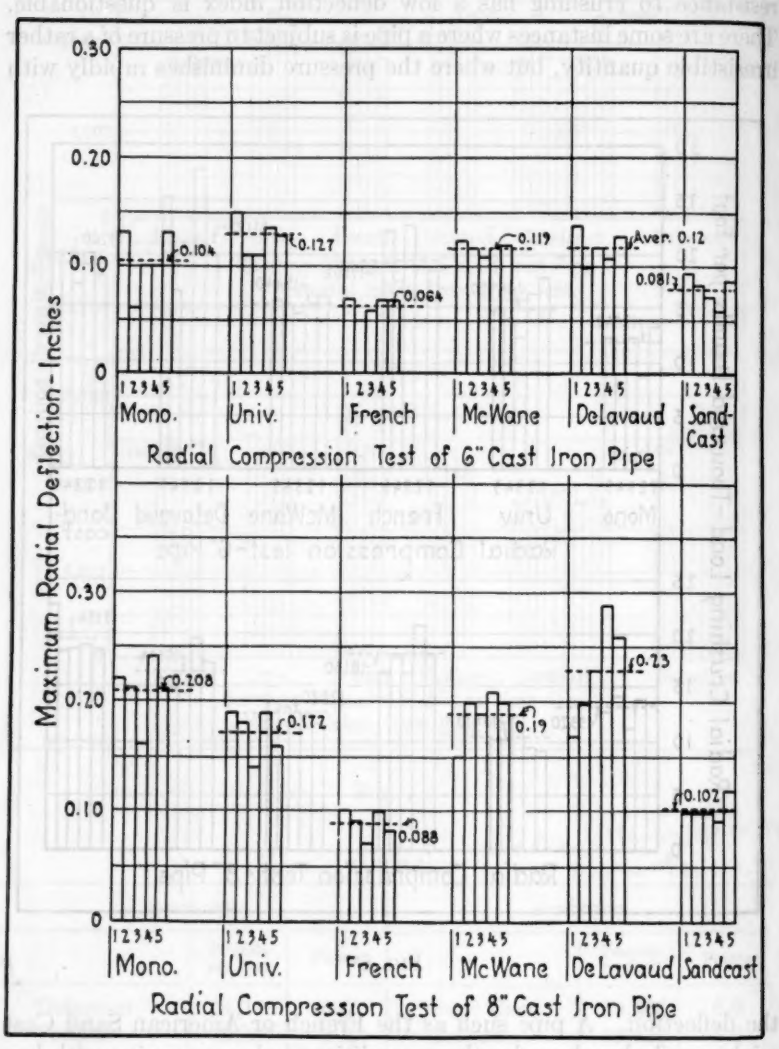

FIG. 9

would demand a stiffer pipe with a greater resistance to bending. So the greater radial deflection of the centrifugal pipe does not necessarily indicate a superior pipe as it lies in the ground in service.

Figure 9 shows the relative amounts of deflection of the various pipes including the Sand Cast and Delavaud previously tested. Here again the French and Sand Cast ran low in deflection values. Considering large deflection before failure as a desirable quality the pipes arranged in the order of quality are as given in table 7.

The radial compression tests were set up as shown in figure 1d.

Preceding the actual test the thickness of each pipe was carefully measured at its thin section and at a point diagonally opposite which was generally the thick section, and then again at points midway between the thin and thick section on either side. A white chalk mark was drawn along the pipe at the thin section and this mark was placed uppermost during the test for resistance to radial compression.

Each specimen was carefully measured for length and found to be

TABLE 7 Radial deflection

6-INCH PIPE			8-INCH PIPE		
	Deflection	Points		Deflection	Points
	inch			*inch*	
Universal	0.127	6.0	Delavaud	0.230	6.0
Delavaud	0.120	5.4	Monocast	0.208	5.2
McWane	0.119	5.3	McWane	0.190	4.6
Monocast	0.104	4.2	Universal	0.172	4.0
Sand Cast	0.081	2.4	Sand Cast	0.102	1.3
French	0.064	1.0	French	0.088	1.0

generally very close to 18 inches. Later the load at failure was reduced to a 1-foot length.

The load was transmitted to the pipe through soft wood cushions at top and bottom to insure reasonably even distribution. The load was applied slowly, and the corresponding inside deflection was read accurately to 0.01 inch, and an estimate was made to 0.001 inch. Only that load was recorded at which the failure occurred.

The resistance to crushing or radial compressive strength is shown graphically in figure 8.

Transverse resistance

Figures 10 and 11 show the results of the transverse tests as well as the test specimen and method of testing. This test is not greatly different from the radial compression test, although the latter has a direct quantitative application and for that reason is more valuable.

It is noticeable, however, that in both the 6- and the 8-inch pipe three of the pipes fall consistently in the higher three groups for both

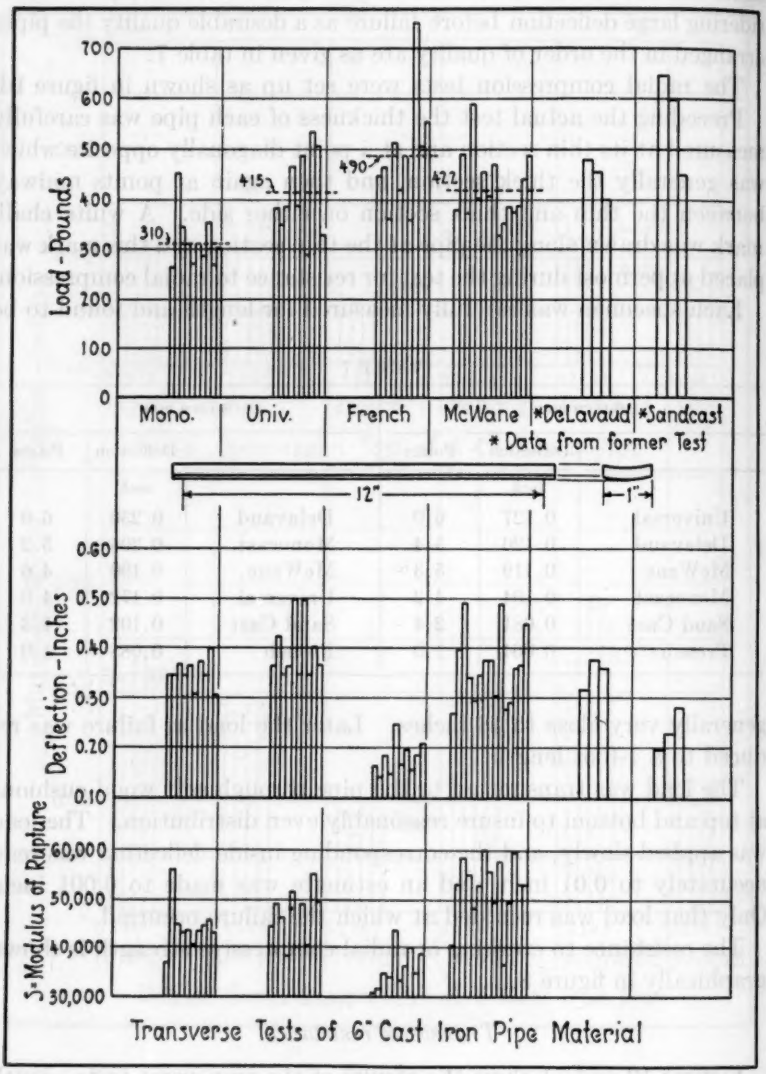

FIG. 10

tests. It was to be expected that the Sand Cast and French pipe should run high in those tests because of their thickness, but the

Delavaud manages to measure up with them although it belongs to the thinner pipe group.

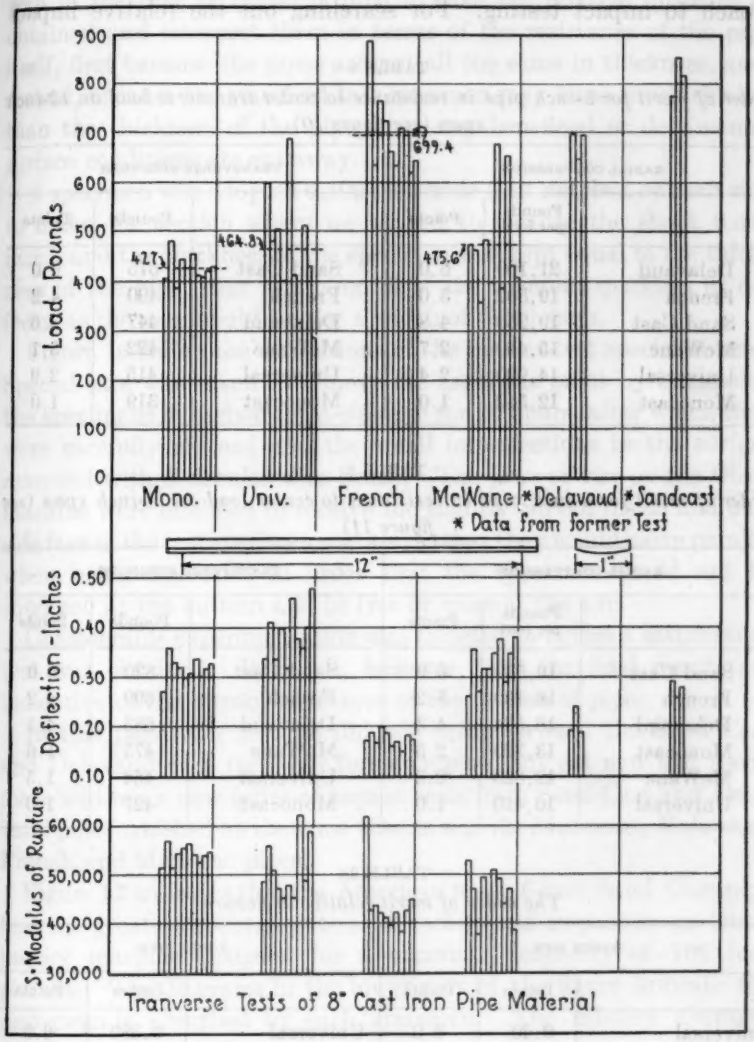

FIG. 11

Tables 8 and 9 show the relative order in which 6- and 8-inch pipe resist transverse loading, and parallel with them the order of resistance to radial compression, for easy comparison.

Impact resistance

As previously stated we were not satisfied with the usual approach to impact testing. For searching out the relative impact

TABLE 8

Order of merit for 6-inch pipe in resistance to center transverse load on 12-inch span (see figure 10)

RADIAL COMPRESSION			TRANSVERSE STRENGTH		
	Pounds per foot	Points		Pounds	Points
Delavaud	21,100	6.0	Sand Cast	575	6.0
French	19,502	5.0	French	490	4.2
Sand Cast	19,260	4.8	Delavaud	447	3.6
McWane	15,440	2.7	McWane	422	3.1
Universal	14,920	2.4	Universal	415	2.9
Monocast	12,542	1.0	Monocast	319	1.0

TABLE 9

Order of merit for 8-inch pipe in resistance to center load on 12-inch span (see figure 11)

RADIAL COMPRESSION			TRANSVERSE STRENGTH		
	Pounds per foot	Points		Pounds	Points
Sand Cast	19,550	6.9	Sand Cast	820	6.0
French	18,130	5.2	French	699	4.2
Delavaud	16,534	4.3	Delavaud	683	4.1
Monocast	13,320	2.5	McWane	475	1.6
McWane	12,820	2.3	Universal	464	1.5
Universal	10,410	1.0	Monocast	427	1.0

TABLE 9A

The order of merit relative to flexure

6-INCH PIPE			8-INCH PIPE		
	Inches	Points		Inches	Points
Universal	0.40	6.0	Universal	0.389	6.0
McWane	0.363	5.1	McWane	0.328	4.5
Monocast	0.354	4.9	Monocast	0.318	4.3
Delavaud	0.35	4.8	American Sand Cast	0.28	2.4
American Sand Cast	2.237	2.2	Delavaud	0.21	1.6
French	0.182	1.0	French	0.175	1.0

resistances of several materials, a standard specimen such as the 0.409 by 0.315 inch size with a slot or notch is acceptable, but there is no way in the case of cast-iron pipe to take the relative qualities so obtained and interpret them in terms of the resistance of the pipe itself, first because the pipes are not all the same in thickness, and, second, because the standard test specimen may be so much smaller than the thickness of the pipe, that any beneficial or detrimental surface conditions are cut away.

A specimen was adopted 0.409 inch wide (but notched on each side to make the section where we wished to localize the shock 0.340 inch), and the thickness of the specimen was kept equal to the thickness of the pipe, thus retaining all of the inherent qualities or defects, as the case might be, for a width of 0.340 inch.

Figure 1a shows the dimensions of the impact-test specimen used. Special care was taken to remove the asphaltic paint by immersing the specimens in carbon tetra-chloride for 24 hours, after which they were carefully cleaned and the small imperfections in the surface removed with a circular wire brush. The jaws or vise on the Olsen machine were modified to receive the slightly curved inside and outside face of the test specimen and also so that they would move parallel when being tightened in order that the specimen would not be squeezed at the bottom and be free or loose at the top.

Considerable experimentation was resorted to before a satisfactory test was obtained. It is felt, however, that the final results are indicative of the impact resistance of the section of pipe.

In this particular test we did not bring forward the Sand Cast and Delavaud data from our former report, but cut new test specimens and ran a new series of impact tests from Sand Cast and Delavaud pipe furnished at the same time as was the Monocast, Universal, French, and McWane pipes.

Figure 12 indicates that the American made 6-inch Sand Cast pipe has the greatest resistance to a 20 foot-pound impact in an Olsen impact machine designed for a maximum capacity of 100 foot pounds. The diagrams in the lower part of the figure indicate the inch-pounds absorbed by each specimen. The relative averages are shown in table 10.

The upper part of figure 12 shows the relative thicknesses of the specimens tested and recorded in the lower part of the figure. It will be noted that the Sand Cast and French pipe are much thicker than the other makes. This thickness probably accounts for the high

relative standing shown by the Sand Cast pipe. On the other hand the French specimens showed the least resistance to impact (0.528 foot-pound) which seems to indicate that the quality of the material as regards shock resistance must be very low for had the pipe been as thin as McWane, for instance, undoubtedly the impact resistance

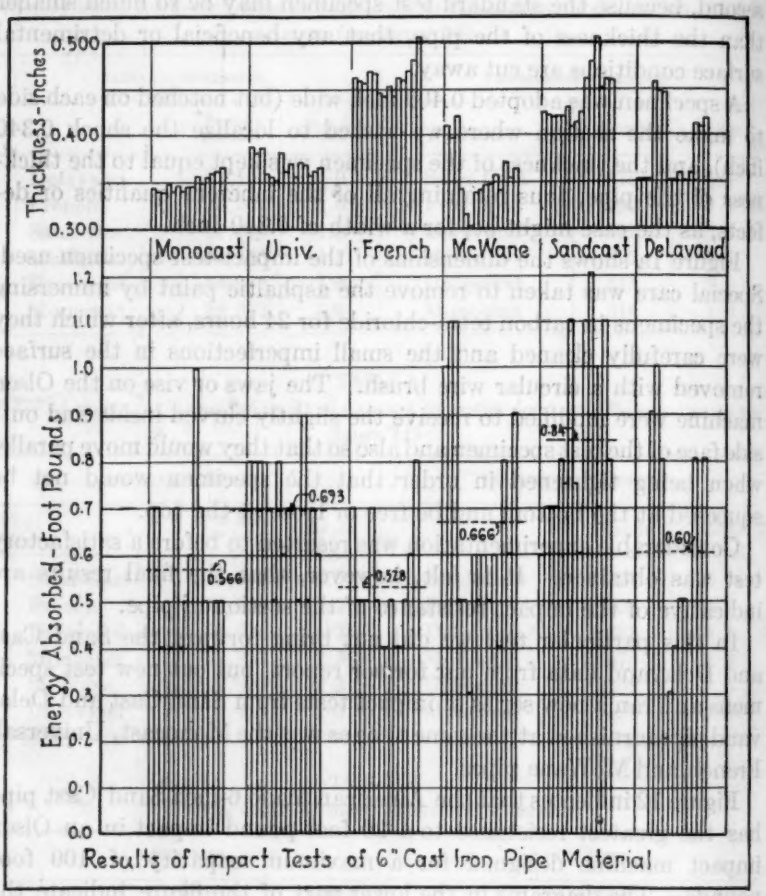

FIG. 12

would be still less than 0.528 foot pound out of a total of 20. It should be further noted that several of the French impact specimens not only fractured right sectionally at the side notches but that they split longitudinally, the cracks generally running in what would be a radial direction, or from the outside to the inside of the pipe.

Figure 13 shows the results of the impact tests on specimens from the 8-inch pipe. These specimens are listed in the order of their resistance to impact in table 11.

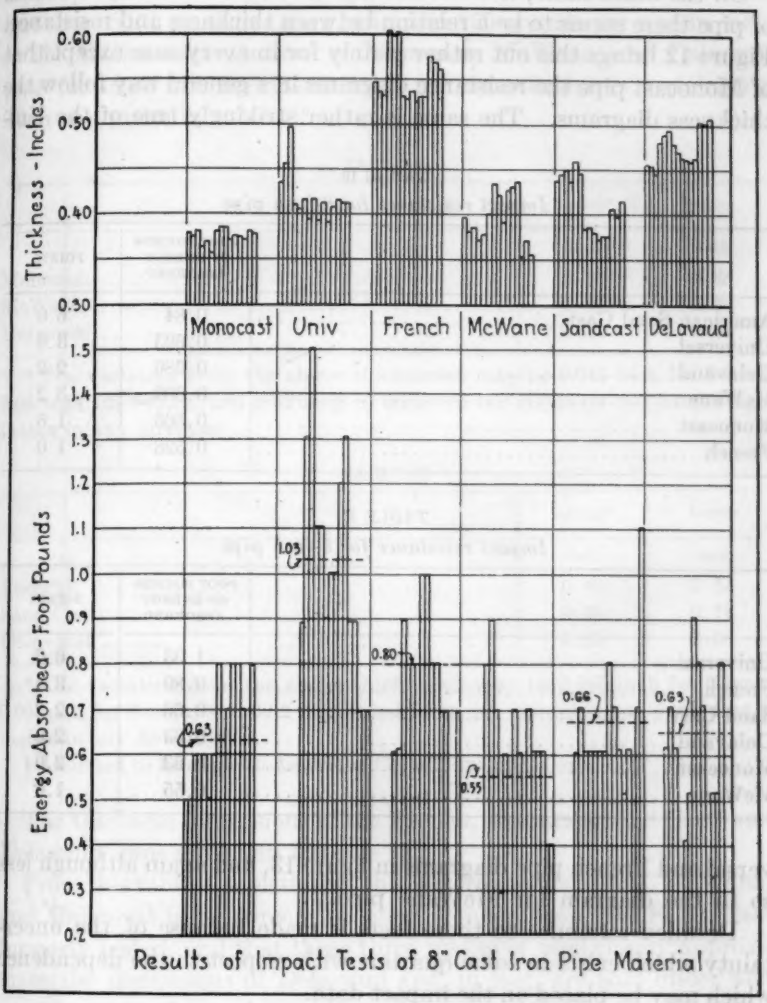

FIG. 13

Attention is invited to the thickness of the French pipe (see fig. 13). With an average of about 0.55 inch, it easily ranks first in thickness but a low second in impact resistance. This and other

similar comparisons from figures 12 and 13 show plainly that a thick pipe of one make does not necessarily mean that its resistance to impact is greater than that of a thinner pipe of another make.

On the other hand, it is interesting to note that on any one kind of pipe there seems to be a relation between thickness and resistance. Figure 12 brings this out rather plainly for in every case except that of Monocast pipe the resistance diagrams in a general way follow the thickness diagrams. The same is rather strikingly true of the Universal and French pipe diagrams in figure 13, and again although less so in the diagram for McWane pipe.

TABLE 10

Impact resistance for 6-inch pipe

	FOOT POUNDS OF ENERGY ABSORBED	POINTS
American Sand Cast	0.84	6.0
Universal	0.693	3.6
Delavaud	0.686	2.2
McWane	0.600	3.2
Monocast	0.566	1.6
French	0.528	1.0

TABLE 11

Impact resistance for 8-inch pipe

	FOOT POUNDS OF ENERGY ABSORBED	POINTS
Universal	1.03	6.0
French	0.80	3.8
Sand Cast	0.66	2.2
Delavaud	0.63	2.0
Monocast	0.63	2.0
McWane	0.55	1.0

Detailed reference to these facts is made because of the uncertainty which exists in some quarters with respect to the dependence which may be placed on the impact data.

Variation in thickness

At the present time the old classification of the American Water Works Association and similar A. S. T. M. standards as regards

Classes A, B, C, D, and so on, meaning pipe intended for working pressures of 43, 86, 130, and 173 pounds, respectively, are not used as exclusively as formerly. The American made pipe herein studied and reported is known as class 150, meaning that the allowable internal working pressures may run up to 150 pounds per square inch.

The thickness dimensions of Monocast, McWane, and Universal pipe for class 150 are taken from the manufacturers' catalogues. They are given in table 12.

TABLE 12

	6-INCH*	8-INCH
	inch	*inch*
Monocast	0.36	0.38
McWane	0.38	0.40
Universal	0.33	0.37

* The variation from the above thicknesses may be 0.045 inch for 6-inch, 0.05 inch for 8-inch, and 0.02 inch in addition for distances not exceeding 8 inches in any direction.

TABLE 13

	6-INCH*	8-INCH
	inch	*inch*
French†	0.48	0.51
Sand Cast	0.48	0.51
Delavaud	0.35	0.38

* The variation from the above thicknesses may be 0.045 inch for 6-inch, 0.05 inch for 8-inch, and 0.02 inch in addition for distances not exceeding 8 inches in any direction.

† Assumed to be made to American Class B specifications.

The thickness dimensions of the French, American Sand Cast[6] and Delavaud[5] pipe are given in table 13.

From this table it is plain that the cast iron in Monocast, McWane, and Universal is 20 percent or more thinner than the Sand Cast formerly tested, and that these three makes of pipe closely approximate the dimensions of Delavaud and, in fact, are sold under and are known to the trade as "Class 150," as is Delavaud, instead of class B, as is the Sand Cast. As nearly as can be told, however, the foreign pipe is made under specifications similar to our old class B Sand Cast pipe, and it will be so considered here.

[6] Pipe formerly reported on but some data brought forward in this report.

In tables 15 to 20 an attempt has been made to show the variation in thickness of the several makes of pipe, giving briefly the specifications for the nominal inside diameter wall thickness and dimensional wall tolerances below this minimum general thickness. The percent variation in thickness based on the minimum thickness is also shown and at the right of each table is shown the acceptability of the pipe for the class to which it is supposed to belong.

All through the study of cast-iron pipe, the question of variation of thickness asserts itself. It has a bearing on the metallurgical property of the iron, the thinner walls being stronger in unit tensile strength, but probably not enough to make the thin wall as strong as the thick one. Bursting tests[7] seem to indicate that failures come at the thin sections. If so, this means that pipe which is not uniform in respect to thickness is wasteful in that the thicker walls cost money all the way along the line, but do not contribute pipe value in proportion to the excess cost. Probably the thick portions of any one pipe have greater impact resistance than have the thinner, but to offset this they contribute to weight without increasing tensile or crushing resistance. This means additional first and handling costs.

Careful measurements of the samples of pipe were made at the time the radial crushing tests were run. Eight measurements were taken on each 18-inch length of pipe; four on each end at opposite ends of elements situated at quarter points of the side placing the thinnest element uppermost.

Instead of attempting to make a clear diagram of the variation in thickness it was necessary to resort to percent variation from the minimum. These percentages and the order of merit of the pipe in this respect are given in table 14.

Variation in weight

Each length of pipe was carefully measured and weighed and the results plotted as shown in figure 14. Here again the similarity between the French pipe tested and reported herein and the Sand Cast previously tested and reported is evident.

It appears that the Monocast pipe is the lightest, if judged from the ten 18-inch lengths studied in this report, although there is little difference between the Monocast, Universal, McWane, and Delavaud in this report.

The average weights per foot are given in table 21.

[7] Talbot and Reichart, A. S. T. M., 1926.

Smoothness

Before making the impact tests, each specimen was thoroughly cleaned of its coating with carbon tetrachloride and brushed on a wire wheel. This brought out the actual surface condition of the pipe and showed the Delavaud to be the smoothest. American Sand Cast and French pipe ranked low in this observation. No

TABLE 14

6-INCH PIPE			8-INCH PIPE		
	Percent	Points		Percent	Points
Delavaud	8.4	6.0	Delavaud	7.8	6.0
Monocast	12.5	4.5	Monocast	8.94	5.7
Sand Cast	22.8	3.1	French	19.64	4.1
McWane	32.9	2.8	McWane	26.7	3.0
French	33.9	2.7	Universal	31.8	2.1
Universal	46.8	1.0	Sand Cast	38.6	1.0

TABLE 15

Variation in thickness of Monocast pipe

6-INCH PIPE
Nominal inside diameter, 6 inches.
Nominal wall thickness, 0.36 inch.
Minimum general wall thickness allowed, 0.315 inch.
Minimum wall thickness limited to 8 inches in any direction, 0.295 inch.

Mark	Actual thickness		Wall thickness, variation	Acceptability for class 150
	Minimum	Maximum		
	inches	*inches*	*percent*	
M_1	0.341	0.383	12.3	Yes
M_2	0.354	0.387	9.1	Yes
M_3	0.350	0.376	6.9	Yes
M_4	0.347	0.387	11.5	Yes
M_5	0.332	0.386	16.2	Yes
M_6	0.342	0.383	12.0	Yes
M_7	0.349	0.391	12.0	Yes
M_8	0.330	0.382	15.7	Yes
M_9	0.339	0.386	13.8	Yes
M_{10}	0.335	0.387	15.5	Yes
Average.....			12.50	

8-INCH PIPE
Nominal inside diameter, 8 inches.
Nominal wall thickness, 0.38 inch.
Minimum general wall thickness allowed, 0.33 inch.
Minimum wall thickness limited to 8 inches in any direction, 0.31 inch.

Mark	Actual thickness		Wall thickness, variation	Acceptability for class 150
	Minimum	Maximum		
	inches	*inches*	*percent*	
M_1	0.353	0.391	10.7	Yes
M_2	0.367	0.391	6.5	Yes
M_3	0.360	0.388	7.8	Yes
M_4	0.364	0.381	4.5	Yes
M_5	0.329	0.387	17.6	Yes
M_6	0.370	0.388	4.8	Yes
M_7	0.355	0.389	9.6	Yes
M_8	0.346	0.387	11.8	Yes
M_9	0.359	0.389	8.4	Yes
M_{10}	0.353	0.391	7.7	Yes
Average.....			8.94	

rating was given because there was no positive way to determine its relative values, and it was felt that smoothness was a quality subject to extreme variation without influencing quality, but a photograph is included which indicates how they ranked from the appearance of

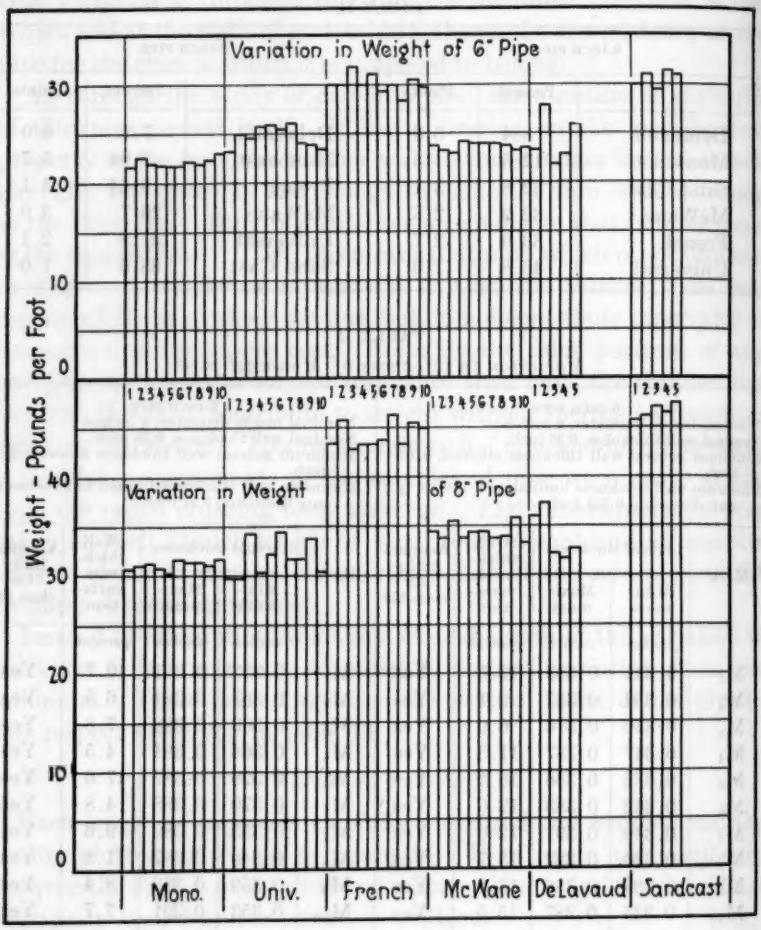

FIG. 14

their surface. It is not thought that the absence of a rating would make any material change in the final rating, since Delavaud is unquestionably the smoothest, whereas observation on the pipe tested leads to the conclusion that all sand cast pipe are apt to have a rougher surface which may vary considerably.

TABLE 16

Variation in thickness of Universal pipe

6-INCH PIPE

Nominal inside diameter, 6 inches.
Nominal wall thickness, 0.33 inch.
Minimum general wall thickness allowed, 0.29 inch.
Minimum wall thickness limited to 8 inches in any direction, 0.27 inch.

Mark	Actual thickness		Wall thickness, variation	Acceptability for class 150
	Minimum	Maximum		
	inches	*inches*	*percent*	
U_1	0.330	0.412	24.5	Yes
U_2	0.343	0.497	44.9	Yes
U_3	0.263	0.405	54.2	No
U_4	0.295	0.420	43.6	Yes
U_5	0.277	0.437	57.5	No
U_6	0.357	0.486	36.1	Yes
U_7	0.325	0.490	50.3	Yes
U_8	0.315	0.521	65.4	Yes
U_9	0.325	0.500	53.8	Yes
U_{10}	0.321	0.445	38.6	Yes
Average			46.8	

8-INCH PIPE

Nominal inside diameter, 8 inches.
Nominal wall thickness, 0.37 inch.
Minimum general wall thickness allowed, 0.33 inch.
Minimum wall thickness limited to 8 inches in any direction, 0.31 inch.

Mark	Actual thickness		Wall thickness, variation	Acceptability for class 150
	Minimum	Maximum		
	inches	*inches*	*percent*	
U_1	0.320	0.425	27.5	Yes
U_2	0.325	0.433	35.2	Yes
U_3	0.355	0.458	24.3	Yes
U_4	0.332	0.403	21.3	Yes
U_5	0.329	0.492	49.5	Yes
U_6	0.332	0.444	33.7	Yes
U_7	0.325	0.423	30.1	Yes
U_8	0.309	0.441	42.7	No
U_9	0.325	0.426	31.1	Yes
U_{10}	0.342	0.421	23.1	Yes
Average			31.8	

TABLE 17

Variation in thickness of French pipe

6-INCH PIPE

Nominal inside diameter, 6 inches.
Nominal wall thickness, 0.48 inch.
Minimum general wall thickness allowed, 0.40 inch.
Minimum wall thickness limited to 8 inches in any direction allowed, 0.38 inch.

Mark	Actual thickness		Wall thickness, variation	Acceptability for class B
	Minimum	Maximum		
	inches	*inches*	*per cent*	
F_1	0.430	0.550	27.9	Yes
F_2	0.400	0.583	45.7	Yes
F_3	0.448	0.609	35.9	Yes
F_4	0.412	0.563	36.7	Yes
F_5	0.430	0.585	36.1	Yes
F_6	0.427	0.530	24.1	Yes
F_7	0.410	0.585	42.7	Yes
F_8	0.415	0.520	25.3	Yes
F_9	0.406	0.595	46.5	Yes
F_{10}	0.435	0.518	19.0	Yes
Average			33.9	

8-INCH PIPE

Nominal inside diameter, 8 inches.
Nominal wall thickness, 0.51 inch.
Minimum general wall thickness allowed, 0.43 inch.
Minimum wall thickness limited to 8 inches in any direction allowed, 0.41 inch.

Mark	Actual thickness		Wall thickness, variation	Acceptability for class B
	Minimum	Maximum		
	inches	*inches*	*per cent*	
F_1	0.483	0.605	25.2	Yes
F_2	0.538	0.617	16.4	Yes
F_3	0.477	0.623	30.6	Yes
F_4	0.488	0.606	24.2	Yes
F_5	0.492	0.600	21.9	Yes
F_6	0.489	0.614	25.6	Yes
F_7	0.512	0.607	18.5	Yes
F_8	0.504	0.559	10.9	Yes
F_9	0.547	0.578	5.7	Yes
F_{10}	0.516	0.606	17.4	Yes
Average			19.6	

TABLE 18

Variation in thickness of McWane pipe

6-INCH PIPE
Nominal inside diameter, 6 inches.
Nominal wall thickness, 0.38 inch.
Minimum general wall thickness allowed, 0.335 inch.
Minimum wall thickness limited to 8 inches in any direction allowed, 0.315 inch.

Mark	Actual thickness		Wall thickness, variation	Acceptability for class 150
	Minimum	Maximum		
	inches	*inches*	*percent*	
W_1	0.336	0.487	45.0	Yes
W_2	0.330	0.425	28.8	?
W_3	0.321	0.387	27.5	?
W_4	0.332	0.455	37.1	?
W_5	0.323	0.483	49.5	?
W_6	0.360	0.438	21.6	Yes
W_7	0.291	0.467	60.5	No
W_8	0.356	0.415	16.5	Yes
W_9	0.325	0.400	23.5	?
W_{10}	0.347	0.416	19.8	Yes
Average.....			32.9	

8-INCH PIPE
Nominal inside diameter, 8 inches.
Nominal wall thickness, 0.40 inch.
Minimum general wall thickness allowed, 0.35 inch.
Minimum wall thickness limited to 8 inches in any direction allowed, 0.33 inch.

Mark	Actual thickness		Wall thickness, variation	Acceptability for class 150
	Minimum	Maximum		
	inches	*inches*	*percent*	
W_1	0.377	0.500	32.6	Yes
W_2	0.377	0.444	17.8	Yes
W_3	0.376	0.455	21.5	Yes
W_4	0.370	0.408	10.3	Yes
W_5	0.375	0.505	34.7	Yes
W_6	0.384	0.441	14.5	Yes
W_7	0.362	0.527	45.6	Yes
W_8	0.373	0.498	33.5	Yes
W_9	0.387	0.418	23.5	Yes
W_{10}	0.363	0.484	33.3	Yes
Average.....			26.7	

TABLE 19

Variation in thickness of sand-cast pipe

6-INCH PIPE
Nominal inside diameter, 6 inches.
Nominal wall thickness, 0.48 inch.
Minimum general wall thickness allowed, 0.40 inch.
Minimum wall thickness limited to 8 inches in any direction allowed, 0.38 inch.

Mark	Actual thickness		Wall thickness, variation	Acceptability for class B
	Minimum	Maximum		
	inches	*inches*	*percent*	
S_1	0.440	0.533	21.1	Yes
S_2	0.431	0.537	24.6	Yes
S_3	0.428	0.504	17.7	Yes
S_4	0.440	0.546	24.1	Yes
S_5	0.427	0.541	26.6	Yes
Average.....			22.8	

8-INCH PIPE
Nominal inside diameter, 8 inches.
Nominal wall thickness, 0.51 inch.
Minimum general wall thickness allowed, 0.43 inch.
Minimum wall thickness limited to 8 inches in any direction allowed, 0.41 inch.

Mark	Actual thickness		Wall thickness, variation	Acceptability for class B
	Minimum	Maximum		
	inches	*inches*	*percent*	
S_1	0.486	0.735	51.3	Yes
S_2	0.487	0.615	26.9	Yes
S_3	0.475	0.668	42.2	Yes
S_4	0.461	0.685	48.7	Yes
S_5	0.539	0.667	23.9	Yes
Average.....			38.6	

CONCLUSIONS FROM PHYSICAL TESTS

A review of the history of cast iron pipe testing plainly indicates that the three properties considered of prime importance are: (1) high tensile strength, (2) high resistance to bending, but great flexibility, and (3) high resistance to impact. Unfortunately, it is not possible as yet for one make of pipe to easily attain superiority in

TABLE 20

Variation in thickness of centrifugally-cast pipe, Delavaud

6-INCH PIPE Nominal inside diameter, 6 inches. Nominal wall thickness, 0.035 inch. Minimum wall thickness allowed, 0.305 inch.					8-INCH PIPE Nominal inside diameter, 8 inches. Nominal wall thickness, 0.38 inch. Minimum wall thickness allowed, 0.335 inch.				
Mark	Actual thickness		Wall thickness, variation	Acceptability for class 150	Mark	Actual thickness		Wall thickness, variation	Acceptability for class 150
	Minimum	Maximum				Minimum	Maximum		
	inches	*inches*	*percent*			*inches*	*inches*	*percent*	
D_1	0.352	0.431	21.3	Yes	D_1	0.414	0.456	10.2	Yes
D_2	0.430	0.446	3.7	Yes	D_2	0.425	0.456	7.3	Yes
D_3	0.343	0.361	5.0	Yes	D_3	0.383	0.401	4.7	Yes
D_4	0.352	0.365	3.7	Yes	D_4	0.375	0.388	3.5	Yes
D_5	0.402	0.443	10.2	Yes	D_5	0.372	0.423	13.1	Yes
Average.....			8.8		Average.....			7.8	

TABLE 21

6-INCH PIPE			8-INCH PIPE		
	Pounds per foot	Points		Pounds per foot	Points
Monocast	22.1	6.0	Monocast	31.1	6.0
McWane	23.4	5.2	Universal	31.6	5.9
Delavaud	24.1	4.8	McWane	34.1	5.1
Universal	25.8	3.8	Delavaud	34.5	4.9
French	29.9	1.4	French	3.98	3.2
American Sand Cast	30.4	1.0	American Sand Cast	4.63	1.0

all three of these tests. High tensile strength may mean hardness accompanied by brittleness and low resistance to impact. Great flexural resistance generally means superiority in radial crushing resistance, but inferiority as regards shock or tendency to suddenly snap under forces which produce bending.

A pipe full of water under pressure has a tensile stress tangent to

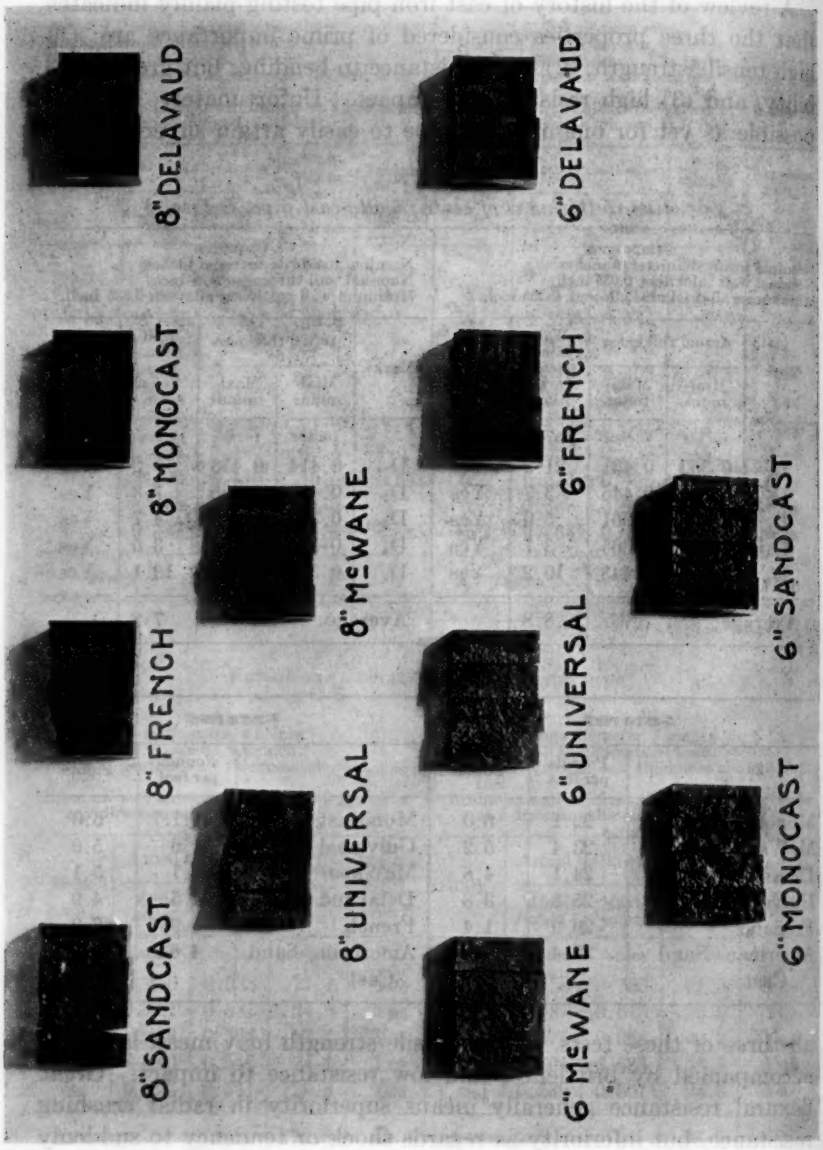

FIG. 15. INSIDE SURFACES OF PIPE

the circumference and not longitudinal as had the test specimens used. Some investigators believe that there is a difference between the circumferential and longitudinal tensile resistance, but there is no good metallurgical reason why there should be, and no direct proof that there is. It therefore seems justifiable to reason from the known tensile strength of the various pipe longitudinally, to its circumferential bursting strength. This permits a great saving in the cost of determining the tensile strength in that the tensile-test specimen may be substituted for a piece of pipe rigged up for an internal hydraulic bursting test.

These and other pipe characteristics which have been considered are

Tensile strength
Radial compressive strength
Transverse bending strength
Radial deflection
Transverse deflection
Impact resistance
Variation in thickness
Weight

It is recognized that there may not be general agreement as to the relative importance of the various attributes and that by changing the above order in a grading system a different final rating might be obtained. Several engineers were consulted as to their opinion in regard to the relative importance of the various tests, and the above order seems to be the nearest quantitative way of expressing that composite opinion. All agree that tensile resistance is of more importance than the others, some considered it twice as important.

Furthermore, it is conceded that a larger number of samples, from a larger number of pipe might bring the conclusions nearer the truth, but practical considerations of cost, and the fact that this investigation had as its main purpose a comparison of foreign with domestic pipe leads to the belief that even though a change in weighting were made, the final results in this respect would not be changed.

It should be again mentioned that this investigation was in part a continuation of a study of three years ago and that Delavaud and American Sand Cast pipe may be of better quality now than then. And in justice to the Monocast and to the other pipe, it should be said that the 8-inch Monocast pipe chosen proved to be high in tension and hard in comparison with the 6-inch Monocast pipe. Lack of

FIG. 15. INSIDE SURFACES OF PIPE

time after this was discovered prevented a substitution. The final rating on Monocast is for that reason passed in with reservation, with the possibility of a check test on 8-inch Monocast at a later date.

These ratings for each quality as determined by the various physical tests are shown in tables 22 and 23, in such a way that the points credited to any one make of pipe may be totaled. The first item considered is tension. Each rank held by a pipe is multiplied by two and another rank taken from table 4 is added in. Table 4 is the computed tensile resistance in bursting based on the unit tensile strength of the thinnest piece of pipe multiplied by the thinnest section found. Thus the first two items in the table make a weight of three for tensile strength.

The next two items make a weight of two for resistance to bending radially and transversely.

The next two items, namely, radial deflection and transverse deflection give a weight of two for the flexibility index.

Impact is the next item. The relative ranks between 1 and 6 in tables 10 and 11 are multiplied by 2 to give the weight here chosen.

The next two items, per cent variation in thickness and weight, are used as taken from tables 14 and 21, respectively, and without any factor.

The weight thus given the various properties of the pipes as determined by the different physical tests is shown below:

TESTS	WEIGHT	
Tensile strength	2	3
Bursting strength	1	
Radial compressive strength	1	2
Transverse compressive strength	1	
Radial deflection	1	2
Transverse deflection	1	
Impact resistance	2	
Uniformity in thickness	1	
Weight	1	

From the ratings obtained in tables 22 and 23, it appears that both 6- and 8-inch pipe made by the same process need not be

equally desirable as pipe, for diameter and thickness have a distinct bearing on its resistance to the various service requirements. But the difference in standing between a 6- and an 8-inch pipe of the same make can be accounted for in variations from the standard dimensions and metallurgical practice in the foundry. Previous tests and also the literature on pipe tests bear this out.

From these tests it appears that the Delavaud pipe has improved since the tests made and reported in 1928. It will be noted that in

TABLE 22

Compilation of ratings in 6-inch pipe

KIND OF TEST	MONO-CAST	UNI-VERSAL	FRENCH	MC WANE	DELA-VAUD	AMERI-CAN SAND CAST
Tensile multiplied by 2	4.6	8.0	3.6	10.0	12.0	2.0
Bursting (computed)	1.0	2.6	2.9	4.4	6.0	2.3
Radial compression	1.0	2.4	5.0	2.7	6.0	4.8
Transverse resistance	1.0	2.9	4.2	3.1	3.6	6.0
Radial deflection	4.2	6.0	1.0	5.3	5.4	2.4
Transverse deflection	4.9	6.0	1.0	5.1	4.8	2.2
Impact multiplied by 2	3.2	7.2	2.0	6.4	4.4	12.0
Per cent variation, thickness	4.5	1.0	2.7	2.8	6.0	3.1
Weight	6.0	3.8	1.4	5.2	4.8	1.0
	30.4	40.9	23.8	45.0	53.0	35.8

Order of rank of 6-inch pipe from above table

Delavaud	53.0	= 10
McWane	45.0	= 8.5
Universal	40.9	= 7.7
American Sand Cast	35.8	= 6.8
Monocast	30.4	= 5.3
French	23.8	= 4.5

the tests herein reported new Delavaud pipe was used for the radial compression and impact tests and that there was a notable higher resistance to radial compression and a greater relative deflection, both of which contributed to its higher standing in the present report.

It further appears that the French pipe ranks at the bottom of the list in 6-inch and third from the bottom in the 8-inch group.

In tables 22 and 23 the points of relative merit have been multiplied by the factor chosen and totaled. But due to the fact that all

pipe passed specifications under which they were manufactured, and sold, it seemed that each pipe should receive a rating of 100 plus whatever it gained by reason of its relative performance in these tests. This in effect is equivalent to saying that any of these pipes will function to a degree that should satisfy the ordinary uses to which pipe are put.

After obtaining the totals in tables 22 and 23 the maximum rating was reduced to 10 and the rest proportionately. They were then all added to 100 with the relative final rating shown in table 24.

TABLE 23

Compilation of ratings in 8-inch pipe

KIND OF TEST	MONO-CAST	UNI-VERSAL	FRENCH	MC WANE	DELA-VAUD	AMERI-CAN SAND CAST
Tensile multiplied by 2	12.0	6.6	3.2	5.6	9.4	2.0
Bursting (computed)	3.2	1.9	2.9	2.2	6.0	1.0
Radial compression	2.5	1.0	5.2	2.3	4.3	6.0
Transverse resistance	1.0	1.5	4.2	1.6	4.1	6.0
Radial deflection	5.2	4.0	1.0	4.6	6.0	1.3
Transverse deflection	4.3	6.0	1.0	4.5	1.6	2.4
Impact multiplied by 2	4.0	12.0	7.6	2.0	4.0	4.4
Per cent variation, thickness	5.7	2.1	4.1	3.0	6.0	1.0
Weight	6.0	5.9	3.2	5.1	4.9	1.0
	43.9	41.0	32.4	30.9	46.3	25.1

Order of rank of 8-inch pipe from above table

Delavaud	46.3	= 10.0
Monocast	43.9	= 9.5
Universal	41.0	= 8.9
French	32.4	= 7.0
McWane	30.9	= 6.7
American Sand Cast	25.1	= 5.4

CHEMICAL TESTS

A chemical analysis was made on each one of the types of pipe examined. The method employed was to take one piece from each of the different types and to obtain from that piece representative drillings from the outside to the inside wall of the sections in question. This was done in order that the chemical composition of the entire cross section of each pipe examined might be secured, for it is recognized that in cast iron there may be slight, and in some cases, marked

variations in chemical composition, especially with respect to the amounts of graphitic and combined carbon present from the outside to the center.

Chemical analysis

The results obtained from the chemical analysis made of the various samples of pipe studied in this investigation are given in table 25.

Attention is directed to the very low combined carbon in the Dela-

TABLE 24

6-INCH PIPE		8-INCH PIPE	
Delavaud	110.0	Delavaud	110.0
McWane	108.5	Monocast	109.5
Universal	107.7	Universal	108.9
American Sand Cast	106.8	French	107.0
Monocast	105.3	McWane	106.7
French	104.5	American Sand Cast	105.4

TABLE 25

Chemical analysis of cast iron pipe, in percent

LABORATORY NUMBER	DESIGNATION	CARBON			Si	Mn	S	P
		Total	Graphitic	Combined				
315	F 6	3.35	2.90	0.45	2.02	0.560	0.082	1.11
316	U 6	3.45	2.89	0.56	2.24	0.614	0.142	0.430
317	M 6	3.64	2.98	0.66	1.71	0.587	0.039	0.479
318	D 1	3.60	3.53	0.07	1.95	0.522	0.066	0.560
319	W 6	3.66	2.90	0.76	1.71	0.387	0.082	0.600
320	S 1	3.68	2.97	0.71	1.69	0.648	0.122	0.561

vaud pipe. This is doubtless due to the fact that this pipe is given an anneal after it has been cast, which anneal throws a very considerable amount of the initially present combined carbon into the graphitic state.

Attention is also directed to the relatively high percentage of phosphorus in the French pipe. This was a condition that was expected, as French pipe, because of the nature of the ores from which the pig used in the production of the pipes is obtained, gives a resultant high phosphorus content. The claim is frequently made that

this high phosphorus content produces a pipe inferior to American-made pipe with approximately half of the phosphorus that is found in the French pipe. It is the writers' belief, however, that the inferior test characteristics of the French pipe are due as much to the method employed in its manufacture as to its chemical composition. French pipe is sand cast pipe and should doubtless be compared with American sand cast pipe, and not with the other types of American-made pipe if the influence of chemical composition—especially phosphorus—is to be considered.

CONCLUSION

From the physical tests which have been made it does not appear as if there is much difference between French and American sand cast pipe. However, from the general physical data which have been procured, the writers question the wisdom of recommending any vertical sand cast pipe, be it French or American.

Frederick B. Leopold

Died, September 20, 1929

Frederick B. Leopold was born in Cincinnati, Ohio, June 13, 1865, son of Otto G. and Mary Paddock Leopold.

He was educated in the public schools of Cincinnati. After leaving school at an early age he learned the machinist trade and worked at this trade for about four years. At the age of nineteen he went west to the State of Kansas and took over a government claim and operated a ranch for about five years. In the year 1889 he returned to Cincinnati and joined the Baughan Engineering Company, contractors for water works and power plants. He was Secretary of this Company until 1895 at which time he joined the We-Fu-Go Company in Cincinnati as salesman for water softening equipment. He remained with this company until January 1, 1902 and then joined the New York Continental Jewell Filtration Company with headquarters in their Western Office at Chicago. He remained with the New York Company until the Spring of 1905 at which time he joined the Pittsburgh Filter Mfg. Company, at Pittsburgh, Pennsylvania, as Vice President and General Manager. The principal business of the Pittsburgh Company at this time was designing, manufacturing and constructing Water Softening and Water Purification Plants and Mr. Leopold had complete charge of this part of the business. During the years 1914 and 1915 this company built the Municipal Filtration Plant for the City of St. Louis, having a daily capacity of 160,000,000 gallons. This was by far the largest mechanical filtration plant built up to this time and led the way for other large supplies of the mechanical type, practically superseding the slow sand design. Mr. Leopold was one of the early and ardent advocates of concrete design of mechanical filters and designed and built many notable plants during his connection with the Pittsburgh Company.

Mr. Leopold was an inventor of many different pieces of equipment for mechanical filters. He designed and built the first dry chemical feeder.

During the spring of 1922, Mr. Leopold formed the F. B. Leopold Company and was its President until the time of his death on September 20, 1929, at the age of 64.

Mr. Leopold was married at Cincinnati, Ohio, on August 21, 1889 to Catherine Karman who with one son, Frederick O. Leopold, and five daughters survive him.

He was an active member of the American Water Works Association for a long period of years, always taking an active part in all problems pertaining to water works and water purification.

SOCIETY AFFAIRS

THE INDIANA SECTION

At the opening session of the twenty-third annual meeting, only business matters were transacted. After this short session, an inspection of the University buildings and grounds was made followed by an informal luncheon. The meetings were held at Lafayette, Indiana, on March 20 and 21, 1930.

In the afternoon, John A. Bruhn discussed the relation of the public utility to its consumers, emphasizing the necessity of a firm position being taken on adjustments made by the utility, not forgetting that both commercial and domestic patrons of good credit standing can be made firm friends and good customers by extending special credit in time of financial stress.

The method of arriving at stand-by charge by power companies and the necessity for such a charge was given in some detail by Mr. Ross of the Indianapolis Power and Light Company who read a paper prepared by J. C. Stipher.

Mr. Edward Groeniger of Columbus, Ohio, presented a splendid paper on the danger of contaminating a city supply from improper connections in the home, hospital and business establishments. He explained why any connection which may at any time be submerged is a potential danger in case of interruption of pressure in the city supply. Serious infections have come from sterilizing equipment in hospitals. In one case infected material from a typhoid patient in a private house was carried back into the public distribution system. The resulting epidemic cost the city in damages more than $50,000 on account of sickness and deaths which occurred.

Mr. H. H. Brown of Chicago explained the use of the partial payment plan in providing plumbing fixtures. This method of marketing is extending very rapidly in this field, pleasing both the dealer and the customer, and has resulted in the use of sanitary conveniences in homes which otherwise would not have been modernized.

Mr. L. D. Shiveley, of the Indianapolis Water Company, explained the development of their meter reading department and the duties of meter readers. He took the position that a meter reader, in addi-

tion to recording the meter reading, should assure himself of the absence of leaks at the meter; should know that the meter is registering, and if the meter shows unusual registration should determine the cause thereof before leaving the premises. The meter reader watches for new houses, new connections to old houses and checks the occupancy of previously vacant property. All meter readers are trained in a school operated by the Water Company for some weeks before actually engaging in their work. The meter reader is recognized as being an important contact between the utility and the public.

At the evening dinner-meeting, the Association was welcomed to Purdue University and addressed briefly by Dean A. A. Potter of the School of Engineering. Dean L. A. Scipio of Roberts College, Constantinople, who is taking his Doctor's degree at Purdue this year, described the water system at Constantinople. The aqueducts and reservoirs are of very ancient construction and many of them are still in use and in good condition. Dr. H. E. Barnard outlined the work of the White House Conference on Child Health and Protection in a very interesting way.

On Friday morning, two sessions were held simultaneously. In one session the operators of water treatment plants were instructed in methods of testing to determine proper operation of their plants and given opportunity to make the different tests themselves. This was a very popular and important session.

In the general session, C. C. Foutz described the operation of the iron removal plant at La Porte. It consists of aeration, chemical treatment, mixing chamber, settler rapid sand filter and reservoir, the latter constructed to avoid short circuiting. The iron removal is from 3.0 in the raw water to 0.2 p.p.m. in the filter effluent. From 1.5 to 2.0 percent of the filtered water is used in backwashing the filters.

The iron removal and softening plant at Marion was described by J. M. Montgomery of Piqua, Ohio. This subject was discussed by S. M. Van Cleave, Superintendent of the Marion plant. The original structures of the old plant were used as far as possible which reduced the cost of construction. The process consists of aeration, chemical feed, mixing chamber and clarifier followed by recarbonation. At this time lime only is used, the hardness being reduced from 30 grains per gallon to 14 in the finished product. Provision is made for the installation of zeolite softeners at a later date if demand is made for a

more perfectly softened water. At this time the consumers are very well pleased. As the water comes from the gravel wells it meets the Treasury standard from a bacteriological standpoint and is treated to make its appearance better. The cost of lime and coke is $13.10 per million gallons.

Some results of improper well construction and finishing were pointed out in detail by C. W. Klassen of the Illinois State Board of Health. Mr. Klassen also gave methods of sealing and finishing wells which will prevent surface and subsurface contamination by industrial wastes or sanitary sewage.

The subject of well construction and the duties and responsibilities of the well driller were continued by A. C. Fiedler of the United States Geological Survey. Mr. Fiedler pointed out that a well driller must have skill, experience and integrity in order that the customer may be assured of the best possible well the locality affords. He emphasized the necessity for seating the casing in an impervious material and explained satisfactory methods of sealing the joint with concrete.

Water works men are very much interested in fire fighting methods. At this session, Ira Hoagland of New York explained the advantage of automatic sprinkler systems, illustrating his talk with numerous lantern slides showing proper and improper installations and the splendid work automatic sprinklers do in stopping fires soon after they start. He called attention to the fact that 80 percent of the fire loss in American cities is caused by 25 percent of the fires.

At the luncheon meeting, the Association was addressed by Jack J. Hinman, President, and Beekman C. Little, Secretary, of the American Water Works Association. Mr. Hinman gave an illustrated account of his work in South America last summer showing under what very different conditions water purification plants are operated in the tropics.

At the afternoon session, R. E. Tarbett of the United States Public Health Service gave the requirements for certification of public water supplies for use on interstate carriers. In 1920 only about 42 percent of the waters submitted could be certified. At the present time practically all waters submitted meet the requirements of the Service. While the data obtained in the past ten years do not show the effect of certification on public health, it is very obvious that it has been responsible for the improvement of operation of filter plants generally. In discussing this paper, H. E. Jordan of the

Indianapolis Water Company, asked why public health authorities should allow private supplies to be used at all, if they are of such character that cross connections between them and the public supply cannot be permitted. While the effect of unsatisfactory private supplies is limited to small areas, the effect of contact infection of the whole community must be bad.

The advances made in chlorination and the present status of the art were discussed by A. E. Gorman of Wallace and Tiernan. Mr. Gorman stated that 82 percent of all public supplies are chlorinated. He stressed the importance of keeping records of operation. The use of split dose of chlorine has been found very advantageous in the control of microscopic organisms and has resulted in increased filter runs. Prechlorination has increased the certainty with which sterilization may be realized. Ammonia added to the water prior to chlorination has eliminated chlorophenol tastes in all cases tried. The ratio of ammonia to chlorine has been found to vary under conditions found in different locations.

L. S. Finch of the Indiana State Board of Health condemned the lack of laboratory control in so many plants. He insisted that, regardless of the size of plant, every operator should be provided with equipment and space in which to make such tests as the operation of the plant requires. The uncovered reservoir is all too common. No time should elapse without chlorination and proper provision should be made to avoid the delivery of unsterilized water when chlorine cylinders are being changed.

H. E. Jordan, of the Indianapolis Water Company, enumerated and discussed several points which he considers of importance in maintaining satisfactory operation of water treatment plants. "Don't say it—write it" may sound like red tape, but a written record is an accurate one and not dependent upon memory. Every operator should know his watershed and the points at which contamination may enter. Some trained person should observe and record the condition of the raw water hourly. Prechlorination is indicated definitely wherever the finished product contains B. coli in half the samples examined and is of large assistance in the operation of many plants. Final chlorination, particularly, must be under laboratory control. Any operator who cannot make the chlorine test is not competent to be on the job. Mr. Jordan asserted that a plant must appear and be clean, and that a mop and broom are for use in the corners as well as in the middle of a room. He advised the use of uniforms for all

operators. In connection with the operation of municipal water purification plants Mr. Jordan said that a municipal executive discharging a competent employee is as guilty of malfeasance in office as he would be if he stole public funds, since he takes away from the people of the community the safety assured them by the services of a competent man.

The Indiana Well Drillers met with the Indiana Section and following the meeting organized an Association of their own. About fifty were in attendance.

Registration at this meeting of the Indiana Section was about 225.

C. K. CALVERT,
Secretary-Treasurer.

ABSTRACTS OF WATER WORKS LITERATURE[1]

FRANK HANNAN

Key: American Journal of Public Health, 12: 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.

Southend Waterworks Company. Inauguration of Langford Waterworks. Anon. Water and Water Engineering, 31: 370, 447–450, October 21, 1929. The Southend, England, Waterworks Company has now to supply direct a district of 160 square miles and is further obligated to furnish water in bulk to another area of 164 square miles. Before the war, increased demand for water was met by sinking additional wells until thirty-four were in use. Since the war additional water has been procured under Parliamentary act through separate intakes from the Rivers Chelmer, Ter, and Blackwater, which flow through agricultural areas; the only two towns on them have sewage treatment plants. The raw water gravitates to a storage reservoir of 60 million gallons built in two equal sections, thence to the pump station, from where it is forced to the filtration plant. After purification, it flows by gravity through a ½-million-gallon equalizing reservoir to the pumps, which lift it to service reservoirs. The pumping equipment is described briefly. Excess lime is added to portion of the water which then joins the bulk of the flow carrying alumina. After twenty minutes agitation a heavy precipitate settles in the primary settling tanks, the supernatant passing to three contact tanks, each of 2-million-gallon capacity. Carbon dioxide gas is next added, precipitating excess lime; final purification is effected by Paterson filters. Filters are cleansed by use of air and water, the wash water being returned to mixing tanks after it has settled 12 hours. A recovery plant reconverts the waste chalk into lime. The plant has technical supervision and produces at all times water of satisfactory quality.—*Arthur P. Miller.*

Ryburn Dam. Notes on the Construction. Anon. Water and Water Engineering, 31: 370, 451–454, October 21, 1929. Dam is of gravity section, with maximum height of 121 feet, base width of 84 feet, and curved in plan to 700-foot radius. A wood stave pipe, the cost of which in place was figured to be only one-fourth that of steel tube unfixed, diverts the river. Details of building the wood pipe are given. The dam is founded on the rock and hard

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[1] Vacancies on the abstracting staff occur from time to time. Members desirous of coöperating in this work are earnestly requested to communicate with the chief abstractor, Frank Hannan, 285 Willow Avenue, Toronto 8, Ontario, Canada.

shales of the millstone grit. Excavation for foundations and cut-off trench totalled 30,000 cubic yards, maximum monthly rate being 5,400 cubic yards. A saving was made in cost of hauling spoil by using some to cover 5 or 6 feet deep a large dump of paper mill ashes and sludge in the reservoir area. To compensate for this fill 5 inches will be added to the height of the dam. Dam will be concrete, of which 58,000 cubic yards will be needed. Maximum daily run has been 200 cubic yards from two mixers. After experimentation a facing of whinstone chippings concrete was selected. This is being brought up with the dam proper. Cementation of measures below cut-off trench is being done through 3-inch iron tubes brought up through concrete to avoid uplifting of surface measures.—*Arthur P. Miller.*

Blackstone Edge Waterworks. New Works of Oldham, England, Corporation. Anon. Water and Water Engineering, 31: 370, 457–461, October 21, 1929. Seven reservoirs, together with water rights, were purchased from the Rochdale Canal Company under Parliamentary power, two of which have been allotted to Oldham and two to Rochdale, the remaining three being reserved for compensation and canal supplies. The article describes improvements made to the reservoirs and adjustments necessary in order that water can be supplied in the proper proportion to Oldham and Rochdale. The waters collected on the Blackstone Edge moors and retained in these reservoirs are strongly acid and colored with peat. A filtration plant was therefore constructed on the aqueduct line in the Longden End Valley. The filters are of the patent vertical pressure type. Lime and aluminoferric are added to the water by means of pumps at the entrance to each line of filters, of which there are two, and dosage so adjusted that the filtered water retains a slightly acid condition. It is then treated with an additional quantity of lime water to make it alkaline. The production of water is about 2¼ million gallons per day. The article also gives information concerning tunnels leading from the filtration plant to the distribution system, the power plant, and the like.—*Arthur P. Miller.*

Kempton Park Works. New Pumping Station and Primary Filters of London, England, Metropolitan Water Board. Anon. Water and Water Engineering, 31: 370, 461–468, October 21, 1929. The Kempton Park Works have been increased by the addition of a new pumping station, primary, or rapid filters, and additional mains needed to care for increased output. The new works are designed to increase the supply to the northern portion of the Board's area. The new pumping machinery consists of two vertical triple expansion steam engines, each of over 1,000 pump horse power. Considerable space is given to describing these pumps and their lubrication. The primary filter plant consists of 24 filter units with total output of 48 million gallons per day arranged in four batteries, each provided with an automatic controller on the inlet. Each filter unit of reinforced concrete provides a filter area of 416 square feet. The filtering medium is 27 inches of specially graded sand on 5 layers of graded gravel. Filters are of the Paterson type, which employs both air and water for washing. The Paterson underdrain system insures uniform draw-off from the filters and uniform distribution of air and water when washing.

To command the existing slow sand filters, the new rapid ones were elevated and in order that the space under them might be utilized, a sedimentation tank was constructed to serve it as the foundation. The wash water from the filters runs to this tank, wherein the sludge settles. The head of water in the tank forces the sludge out through an appropriate pipe and by means of a high pressure connection to this pipe the sludge is stirred up if it becomes too solid. Mechanically driven air compressors or blowers have been eliminated by discharging the wash water from the elevated tank into either of two 7-foot diameter steel cylinders, thus compressing the air therein, displacing it, and forcing it through the filter beds. This has necessitated building the wash water tank 24 feet higher; but the resultant saving in capital cost of machinery will outweigh this expense. When the air has been expelled from the compressor tank, the water supply is shut off and the water in the compressor tank used for washing the filters.—*Arthur P. Miller.*

Constructing Pardee Dam. JAMES N. HATCH. Public Works, 60: 9, 340-44, September, 1929. In order to supply water to cities east of San Francisco Bay the Pardee dam is being constructed on the Mokelumne River. The reservoir will impound 222,000 acre-feet of water. The dam will rise 360 feet above the present river bed and will contain 625,000 cubic yards of concrete. In order to secure the necessary concrete aggregates, a screening and washing plant was built five miles downstream from the site of the dam. The sand and gravel consists of dredge tailings left by former gold mining operations and still contains sufficient gold to warrant its removal. Aggregates are transported to the dam by means of an aërial tramway which has a capacity of 225 tons per hour. Bunkers having a total capacity of 6000 tons provide adequate storage. Cement is stored in a silo and conveyed to the battery of four 56-S two-yard Smith mixers as needed. Aggregates are measured in a Blaw-Knox batcher and delivered to the mixers on a 30-inch belt conveyor. Construction also includes a 15,000-kilowatt power plant.—*C. C. Ruchhoft.*

Lime for Water Treatment. Abstract of paper by PAUL C. LAUX. Public Works, 60: 267, 1929. Dry feed machines are preferable for applying lime. Feed lines should be short and straight, short bends and curves should be avoided, and rubber hose should be used for horizontal flows.—*C. C. Ruchhoft (Courtesy Chem. Abst.).*

Dams and Control Works Constructed by the Bureau of Reclamation. ELWOOD MEAD, Commissioner, Bureau of Reclamation, Dept. of the Interior, 1929. The Bureau of Reclamation was organized in 1902 and up to the time of the writing of this publication had constructed 125 dams ranging from simple diversion dams of less than 3 feet in height to the huge Arrowrock storage dam with a maximum height of 348.5 feet. The Owyhee Dam, contract for which had been let when the pamphlet was published, will surpass the Arrowrock Dam with an effective height of about 405 feet. Many of these dams have been described in articles published by this Bureau and in its annual reports, but since many of these publications are now out of print, descriptive articles

of typical dams have been collected and republished in this publication. The information given is neither detailed nor technical, inasmuch as such information can be obtained by reference to the original published reports, to be found in libraries. Descriptions, pictures, and designs of six diversion dams and fourteen storage dams are included. In addition, some miscellaneous articles and typical specifications for dams are given.—*Arthur P. Miller.*

The Year in Review: 1928–1929. Public Health News (N. J. Dept. of Health), **14**: 10–11, 227, September–October, 1929. Among accomplishments of New Jersey State Department of Health for year ending June 30, 1929, were the following: (1) A new chapter of State Sanitary Code prohibited new cross connections between public potable water supplies and other, unapproved, supplies, requiring that those in use be equipped with all-bronze double check valves of an approved type, if they were to be retained. (2) The water and sewage laboratory discovered that the reason why *B. coli* was not being eliminated from certain chlorinated water supplies was an error in reading tests which fixed chlorine dosage, due to presence of manganese salts. A method for testing waters for manganese was developed, and with its aid correct dose of chlorine can be found.—*G. C. Houser.*

Recent Regulations of Indiana State Board of Health. Monthly Bulletin, Ind. State Board of Health, **32**: 11, 170, November, 1929. A recently passed rule requires the construction and use of public water supply systems in incorporated cities and towns when the lack of such systems results in conditions causative of disease. Another rule requires the use of proper and adequate treatment in connection with public water supplies derived from surface sources, in order that they shall meet the standards of U. S. Public Health Service.—*G. C. Houser.*

Yonkers Makes Remarkable Typhoid Record. Health News (N. Y. State Dept. of Health), **6**: 39, 155, September 30, 1929. In eight out of 81 cities in the United States of over 100,000 population, no deaths from typhoid fever occurred in 1928. One of these cities was Yonkers, N. Y., which has the exceptional record of having had no deaths from typhoid for the last three years and for five years in all. The diminution in the prevalence of typhoid in general is attributed largely to improvements in public water supplies, though other factors, such as general sanitation, adequate sewage disposal, pasteurization of milk, control of other foodstuffs, and the supervision of typhoid carriers have all played their parts.—*G. C. Houser.*

Watch Your Water Supplies. Health News (N. Y. State Dept. of Health), **6**: 39, 156, September 30, 1929. Early last summer, the State Department of Health warned water supply officials of the probable necessity for using auxiliary water sources if the drought continued, and offered to install emergency chlorination equipment in cases where such auxiliary supplies were not of satisfactory quality. Over 30 municipalities suffered a shortage of water before the drought broke, and the emergency apparatus was called into use in

a number of cases. Despite the unusual conditions no water-borne outbreaks occurred.—*G. C. Houser.*

The Drought and Public Water Supplies. Connecticut Health Bulletin, **43**: 10, 382, October, 1929. The sharp drought prevailing in Connecticut last summer was finally broken by a heavy rainfall during October 1 to 3. Public water supplies in New Hartford and Lakeville were so badly depleted as to necessitate pumping from a river and a lake. Chlorination was installed under the supervision of the State Department of Health. In New Hartford, metering of services is being extended, so as to reduce the probability of future shortages. At Lakeville, a new driven well supply was rapidly constructed and is now used to augment the usual reservoir supply.—*G. C. Houser.*

How to Test Water Supply for Excess Chlorine. Health News (N. Y. State Dept. of Health), **6**: 44, 173, November 4, 1929. The *ortho*-tolidine test for excess chlorine, which shows whether sufficient chlorine is being added to a water to render it safe for drinking purposes, is one which every health officer should make at regular intervals. Directions for making test are given in detail. Experience has shown that most water supplies are chlorinated effectively when the dose provides a residual chlorine concentration between 0.1 and 0.2 p.p.m., after 15 minutes.—*G. C. Houser.*

A Step Forward in Preventing Pollution of the Great Lakes. Health News (N. Y. State Dept. of Health), **6**: 44, 173, November 4, 1929. The health commissioners of 8 states met at Minneapolis on October 2, 1929, and adopted the following resolution: the Departments of Health of the States of New York, Pennsylvania, Ohio, Indiana, Michigan, Illinois, Wisconsin, and Minnesota, signators to the Great Lakes Drainage Basin Sanitation Agreement, hereby agree relative to the treatment of municipal sewage that, when their advice is sought, when plans of municipal sewage treatment works are submitted for approval, or in the issuance of decrees to municipalities relative to the treatment of sewage, the minimum degree of sewage treatment shall be "efficient sedimentation."—*G. C. Houser.*

Filtration of Water Supplies. H. C. CHANDLER. Connecticut Health Bulletin, **43**: 11, 402, November, 1929. In rating the public water supply of a community, one of the most important items to be considered is quality. The four standards of quality, in order of importance, are: safety, taste, chemical balance, and appearance. In order to be certain of perfectly uniform quality at all times, conforming to these four standards in every respect, it is nearly always advisable to resort to modern methods of chemical treatment and filtration. It is the writer's opinion that, in the near future, it will be required by law that all public water supplies shall be filtered, with the exception of certain ground water supplies.—*G. C. Houser.*

Bad Water Causes "Intestinal Flu." Illinois Health Messenger, **1**: 23, 91, December 1, 1929. At first regarded as an outbreak of intestinal flu, a late September epidemic disorder at Riverside, Ill., which involved several

hundred people, turned out to be a water-borne infection, caused by pollution of the public water supply. Upon arrival of a sanitary engineer from the State Department of Health, a chlorinator was installed and the epidemic promptly subsided. Subsequent examination of the well disclosed the fact that it had no casing through the limestone strata which it penetrated. Crevices through this formation allowed contaminated seepage to get into the well.—*G. C. Houser.*

Report of Epidemiologist for September, 1929. W. W. LEE. Monthly Bulletin, Indiana State Board of Health, **32**: 10, 165, October, 1929. Seven cases of typhoid fever in Bedford, Ind., were traced to a spring on a farm. Four cases developed in one family in Paragon. These children lived in a very insanitary home, and the well was the probable source of contamination.—*G. C. Houser.*

Catskill to Have New Water Supply. Health News (N. Y. State Dept. of Health), **7**: 2, 5, January 13, 1930. At a recent election, the taxpayers of Catskill, N. Y., voted for a bond issue of $575,000 for the acquisition of a new source of water supply for the village. It is proposed to impound the waters of the West Branch of Potuck Creek at a point about ten miles northwest of the village. The water will be filtered and chlorinated.—*G. C. Houser.*

What the Quake Did to The Water Supply. Health News (N. Y. State Dept. of Health), **7**: 3, 10, January 20, 1930. Although the public water supply of Attica, N. Y., was somewhat depleted by last summer's drought, since an earthquake shook the town the reservoirs have been overflowing, indicating that the disturbance opened some underground springs. Further evidence was furnished by the fact that certain springs that had been dry suddenly began to yield a good flow of water.—*G. C. Houser.*

Outdoor Public Bathing Places. I. R. RIKER. Public Health News (N. J. Dept. of Health), **15**: 2–3, 36, January–February, 1930. Recently a canvass of New Jersey revealed 349 established bathing places, of which 65 are indoor pools and 54, artificial outdoor pools. Increase may be expected in the number and patronage of artificial pools in the State. Unless such pools are properly designed, constructed, operated, and maintained, the health of large numbers of persons may be adversely affected. Specific legislative authority to regulate pools in New Jersey does not exist at present, but should be given, in the writer's opinion, to local and State health departments jointly.—*G. C. Houser.*

Swimming Pool Supervision in Rhode Island. S. DEM. GAGE. Public Health News (N. J. Dept. of Health), **15**: 2–3, 46, January–February, 1930. The Rhode Island swimming pool law was sponsored by pool owners and operators. It provides that it shall be unlawful for anyone to maintain a swimming pool without a license from the R. I. Public Health Commission. The commission was directed to make such regulations as it might deem

advisable with reference to the condition and maintenance of pools, for the purpose of insuring the health and safety of users thereof. It was directed to inspect all pools at least once a year, and to make chemical and bacteriological analyses of the water in each pool at least twice each month, and report back to the pool owner whether or not the condition of the water is such as to be detrimental to the health of users of the pool.—*G. C. Houser.*

Children Drink From Polluted Pond, Get Typhoid. Public Health News (N. J. Dept. of Health), **15**: 2–3, 57, January–February, 1930. Two cases of typhoid fever and several cases of acute diarrhea occurred early in November among a group of 16 children from Pitman, N. J., who drank polluted water from the Holmwood marl pits. The party went hiking on October 19. Thirst was quenched with water from pits or ponds along a stream which receives the effluent of a sewage disposal plant about half a mile upstream and somewhat later disease followed.—*G. C. Houser.*

Cross Connections. Public Health News (N. J. Dept. of Health), **15**: 2–3, 60, January–February, 1930. On January 11, 1930, Surgeon General CUMMING wrote to all State Health Officers, stating that from that date water supplies used by interstate carriers for drinking and culinary purposes would not be given a full certification if cross connections exist between such supplies and any other supply; except, when such cross connection is with another potable public supply, or a potable supply regularly examined by those in charge of the supply to which cross connected; and except, further, when such cross connections are equipped with modern protective devices approved by the State Department of Health.—*G. C. Houser.*

Waterbury Acts to Prevent Pollution of House Water Piping. Connecticut Health Bulletin, **44**: 2, 38, February, 1930. A newly adopted local regulation by the City of Waterbury, Conn., reads as follows: No flush valve that is installed to flush water closets shall be connected directly to any city water pipe or service pipe in this city, unless such flush valve is provided with proper air breaks to overcome the vacuum created when the water is shut off, and all such valves shall first have the approval of the Plumbing Inspection Department. The object of this rule is to prevent pollution of house water piping from toilet bowls, which has been known to occur thus. If the bowl outlet becomes stopped up so as to fill the bowl above the inlets, and the water is shut off in the cellar, then opening a faucet downstairs would reduce the pipe line pressure and permit, with some types of flushometer valves, polluted water to siphon directly into the water piping system.—*G. C. Houser.*

Unusual Sources of Water Pollution. Health News (N. Y. State Dept. of Health), **7**: 7, 27, February 17, 1930. Cites two examples of pollution of hospital water supplies through poorly designed piping. Nearly four years ago in a hospital in New York City, it was discovered one day that sterilizer, in which infected instruments had been placed, had suddenly gone dry. Investigation showed that a lowering of the water pressure in the building had caused the infected water in the sterilizer to siphon back into the water pipes.

In a Chicago hospital there was a water-still which had a drain connected to the house drainage system by a direct, unbroken connection. On one occasion, the vacuum produced by condensing steam in the still siphoned sewage from the waste and soil pipes up into the still, so that what they had for distilled water was one part of that to 20 or more parts of sewage.—*G. C. Houser.*

Rainfall Characteristics and Their Relation to Soils and Run-off. C. S. JARVIS. Proc. Am. Soc. Civ. Eng., **56**: 1, 3–47, January, 1930. The author presents summarized information regarding precipitation and its occurrence in various countries and latitudes; its relation to soils and run-off; the vegetation, topographic, and physiographic features of the water-shed; and the resultant influence on designs of drainage structures and channels. The factors responsible for both rainfall and run-off are fairly well defined. Wherever meteorological and hydrographic records are available, approximations may be made with varying degrees of dependability as to both the ordinary habits and the extremes of behavior against which provisions should be made.—*John R. Baylis.*

Control of Mineral Waters and Their Salts Under the Federal Food and Drugs Act. J. W SALE. Ind. Eng. Chem., **22**: 332–5, 1930. Adulteration or misbranding of bottled mineral water under this Act is due either to unsanitary quality, or to false statements on the label relating to the therapeutic value of the dissolved chemical substances. A standard of sanitary quality somewhat different from that generally adopted (A. P. H. A.) is used. Strict enforcement of the law in relation to interstate and import shipments of such waters has materially reduced the number of violations.—*Edward S. Hopkins* (*Courtesy Chem. Abst.*).

The Detection of Ammonia Production by Bacteria in Agar Slants. P. ARUE HANSEN. Jour. Bact., **19**: 223–9, 1930. A method for detecting ammonia in agar slant cultures is given. Solutions of thymol and of sodium hypobromite give a blue or greenish blue color if ammonia is present.—*Edward S. Hopkins.*

A Simple Method of Growing Anaerobes in Petri Dish Cultures. B. L. HERRINGTON and GEORGES KNAYSI. Jour. Bact., **19**: 101–3, 1930. The method is a combination. Use of water vapor to sweep away the air has, as compared with the use of inert gases, the advantage that it is the same substance as that in which the bacteria are living. Water vapor prevents the drying of the agar, no matter how long the period of incubation may be.—*Edward S. Hopkins.*

A Sugar Tolerant Member of the Colon Aërogenes Group. LAWRENCE H. JAMES. Jour. Bact., **19**: 145–8, 1930. An organism resembling *Aërobacter cloacae* has been isolated from granulated sugar (sucrose). It actively ferments sucrose in a concentration of sirupy consistency.—*Edward S. Hopkins.*

Increasing the Revenue from Metered Water Systems. ARTHUR T. SEAMAN. American City, 42: 3, 92–94, March, 1930. The City of Chicago, through their meter testing and control division, has made a very careful study for 7 years of the accuracy of various water meter installations in the city. They have developed for this purpose a meter rate recorder, which records the instantaneous meter reading throughout any desired period of time. It is therefore possible, by studying such records, to ascertain suitability of certain sizes and types of meter for various installations. As a result of this study of about 2000 meters, ranging 3-inch and larger in size, it was found desirable to change either the size or type of 25 percent of the meters, with the result that the average increase in registration is 600 cubic feet per day, or about 25 percent, for each meter. Indications are that with meters of 1-inch to 2-inch in size a larger number of replacements will be desirable, but that the resulting increase in registration will be only 15 to 18 percent.—*C. R. Cox.*

Indiana Drilled Well Water Supply. F. E. SHULTZ. American City, 42: 3, 130–134, March, 1930. An 8-inch well was drilled to 1900 feet depth at Columbia City, Indiana, in hopes that gas would be encountered. This was not the case, but water of safe sanitary quality was delivered by the well. Municipal water works were organized in 1894 and this well was used as a source of supply. Two additional 10-inch wells were drilled subsequently to increase the supply. There is no storage of water, so that the rate of pumping has to be adjusted to the consumption. It is stated that the cost of pumping could be reduced about 50 percent were storage provided.—*C. R. Cox.*

Automatic Chlorination of a Gravity Water Supply. PERCY R. SAUNDERS. American City, 42: 3, 94–95, March, 1930. The water supply of Concord, N. H., is secured from Penacook Lake, 3 miles north of the city, which has a catchment area of 3.77 square miles. The lake is fed almost entirely by springs and the water-shed is sparsely settled with a permanent population of about 75 people. All boating on the lake is under supervision of the water works officials. The city owns 98 percent of the shore line and the intake is located 2200 feet from the shore. Consulting engineers for the city recommend that the supply be chlorinated with a small dose of chlorine. An existing venturi meter measures the rate of flow of water to the city which varies from 0.5 to 6.2 m.g.d. Due to this fluctuation in flow it was deemed necessary to install an automatic chlorination apparatus. A Wallace & Tiernan Company automatic control, vacuum fed chlorinator was installed in a gate house. The dose is about 2.5 pounds per million gallons of water. About 6000 gallons of water is used to operate the chlorinator each day. The *ortho*-tolidine test indicates the presence of residual chlorine in the treated water near the point of application, but not in the city or at the pumping station. The apparatus is heated during the winter months by an automatic oil heater with the oil reservoir connected by a small pipe to a 10-gallon tank. It is possible, therefore, to operate this heater for long periods of time without attention. The machine was placed in operation several months before the fact became known to the public and no complaints regarding tastes were received during this

period. Afterwards, however, complaints were received from a number of people relative to alleged objectionable tastes; but such complaints have ceased.—*C. R. Cox.*

Revenue and Expenditure for City Water Department in New York State. American City, **42**: 3, 160, March, 1930. Tabulated data for the year 1928 regarding 49 cities in the state of New York, collected by the New York State Bureau of Municipal Information, which cannot be readily abstracted, indicate the population served, the various sources of revenue, and the various expenditures, arranged in 14 columns. This table is a valuable addition to the literature upon water works finance.—*C. R. Cox.*

The New Storage Facilities of the Pawtucket Water Works. FREDERICK C. WILLIAMS. Journ. New England W. W. Assoc., **43**: 2, 113–32, June, 1929. The City of Pawtucket, R. I., has recently spent approximately one million dollars on new storage facilities for its water works. In order to have sufficient water supply for an increasing population, a development program has been planned which requires the construction of six reservoirs during the 50-year period 1925–75, the first of which is the Arnold Mills project. The dam is 2,900 feet long and of earth fill type. Description is given of construction details and construction methods used.—*H. H. Gerstein.*

Some Distribution Problems. FRED B. NELSON. Journ. New England W. W. Assoc., **43**: 2, 133–42, June, 1929. The introduction in New York City of the Catskill supply, which is delivered by gravity at a much higher head than the original Croton and other supplies, has made possible improvements of pressure and extensions of service zones, and has involved many radical changes in distribution. In order to correspond with the topography of the boroughs of Manhattan and Bronx, the system included four service zones supplied under heads varying with the ground elevation included in each; (1) low service, supplied by Croton water under gravity head; (2) intermediate service, supplied by Croton water, together with Catskill water under reduced and regulated head; (3) high service, supplied by Catskill water by gravity or under full head of Catskill tunnel; (4) tower service of Manhattan, supplied by the Catskill water and Croton water pumped to about 50 feet above the available Catskill head. In general the aim has been to utilize the Croton supply as fully as possible, reserving the Catskill supply for higher areas, in order to save pumping. Pressure surveys which were made to establish gradients available throughout the system, also proved valuable in determining the location and length of new mains necessary for the improvement of pressure conditions. Underground leakage survey uncovered a 6-inch blow-off running wide open and discharging 6 m.g.d. into sewer.—*H. H. Gerstein.*

Electrolysis Investigations. C. F. MEYERHERM. Journ. New England W. W. Assoc., **43**: 2, 143–7, June, 1929. An electrolysis survey, or program, in order to be successful, requires the supervision of an engineer experienced in practical electrolysis problems, who can give a considerable part of his time to the work. Practically all electrolysis problems involve a multiplicity of

underground structures. In order to obtain complete information regarding the electrical relations between these structures, tests must be made on all these systems. A large and varied assortment of indicating and recording instruments, special test apparatus, as well as experienced personnel and effective coöperation with the utilities operating the underground systems, are required. A specially equipped electrolysis truck has been successfully used for survey work in various cities.—*H. H. Gerstein.*

Copper and Brass Water Services. WILLIAM G. SCHNEIDER. Journ. New England W. W. Assoc., **43**: 3, 148–51, June, 1929. Author discusses relative merits of copper and brass, as compared with iron and lead, for water service pipe. The advantages of brass and copper pipe are greater life, freedom from rusting or becoming clogged with rust, and greater strength.—*H. H. Gerstein.*

The Granville Dam at Westfield, Mass. C. A. FARWELL. Journ. New England, W. W. Assoc., **43**: 2, 16–74, June, 1929. New water supply project for Westfield, Mass., calls for an earth embankment dam which will provide storage capacity sufficient to furnish 4 m.g.d., the forecasted requirement from this supply in 1955. Provision is made for raising the dam and reservoir level in the future to an additional height of 18 feet. In order to prevent seepage along original ground surface, a concrete cut off is provided across the floor of the valley extending from the surface downwards to bed rock and upwards about 10 feet. A large number of test pits were dug to determine soil conditions.—*H. H. Gerstein.*

Construction of Granville Dam at Westfield, Mass. E. B. MYOTT. Journ. New England W. W. Assoc., **43**: 2, 175–90, June, 1929. The construction of the Granville Dam involves a total expenditure, exclusive of purchase of land, of $630,000. Description is given of construction methods. The main dam is built by lay-fill method, with stone toe and heel, and stone facing on upstream slope. Great care is taken in compacting embankment material.—*H. H. Gerstein.*

Soil Studies for the Granville Dam at Westfield, Mass. CHARLES TERZAGHI. Journ. New England W. W. Assoc., **43**: 2, 191–223, June, 1929. A very thorough study of the geology and soil conditions on the dam and reservoir site was made with the view of determining the magnitude of water losses due to percolation around the dam, and for judging the suitability of the available materials for dam-construction purposes. Description is given of the various testing methods, as well as of methods of interpretation of results. A quick test for estimating the coefficient of permeability of samples of soil taken from test pits was developed, based on the fact that the speed of capillary rise through soil becomes less as the soil becomes less permeable.—*H. H. Gerstein.*

Who is Legally Responsible for Pollution of Water Supply? LEO T. PARKER. Water Works Eng., **83**: 1, 15, January 1, 1930. Generally speaking, the firm,

or person, who pollutes the water, and not the water company, is liable to the damaged person. Author cites one case where an oil company which added salt and other mineral substances to a water was held liable when these substances injuriously affected a pre-existing water supply. In another case it was held that an engineers' acceptance of work which was performed under his direction was final and that the municipality could not hold up payment of estimates. In another case, court ruled that a septic tank effluent was not injurious to a drinking water supply. Suit had been brought to prevent the construction of a septic tank 150 feet above the location of a spring which was used for a drinking supply.—*Lewis V. Carpenter.*

How a Small Town Water Works Reduced Its Iron Content. T. M. EARLY. Water Works Eng., **83**: 5, 287, February 26, 1930. A water works with daily capacity of 750,000 gallons had an iron content of 1.4 p.p.m. After aëration and filtration the water was still very aggresssive and it was necessary to add approximately 1 grain per gallon of lime to supplement preliminary treatment with 3 grains per gallon of soda ash and 2.25 grains of alum. The pH of raw water was 5.5; aëration raised this to 6.8; and it remained at this point after filtration. Addition of the lime after filtrations brought pH to about 8.0 with a very small CO_2 content.—*Lewis V. Carpenter.*

Removing Color, Tastes, and Odors from a Widely Fluctuating Supply. WILLIAM I. KLEIN and C. ARTHUR BROWN. Water Works Eng., **83**: 5, 283, February 26, 1930. The Westchester Joint Water Board built a 5,000,000-gallon per day gravity filter plant. Supply is from the Mamaroneck River and is very non-uniform in its characteristics. Water passes in succession through Dorr mechanical mixers, Dorr clarifier, settling basins, filters, aërator, and clear water reservoir. The time required between pumps and filters is 3 (three) hours and 20 (twenty) minutes. Alum is used as coagulant. Soda or lime added previously to the alum increased and set the color. Copper sulphate killed the algae, but the dead algae clogged the filter bed and caused objectionable taste and odor which, however, were eliminated by superchlorination and potassium permanganate. Final treatment with soda ash after filtration brought the pH to 7.6. During cold weather it was necessary to add lime to create floc and this caused objectionable color. Chlorinated copperas was therefore used during cold weather with result that color immediately dropped to zero and taste was removed coincidently. About 0.67 g.p.g. of iron sulphate and 0.12 g.p.g. of chlorine were applied with satisfactory results. The average cost of chemicals during past year was $6.57; while with new process, which is simpler and easier to employ and has far wider range of efficiency, it will not exceed $3.00.—*Lewis V. Carpenter.*

When Is the City Liable for Damages Caused by Main Break? LEO T. PARKER. Water Works Eng., **83**: 7, 420, March 26, 1930. In one case where the main broke and caused damages by flooding of the building a few days after the city had been notified that water was seeping through the pavement and had failed to shut it off, the court held the city liable. The law is well established that if the plans of a water works are changed after the contract

has been signed, the contractor is entitled to payment for extras and under certain circumstances is relieved from obligations under the terms of the original contract. Several cases are cited where the court has ruled that contracts are against public policy, if the circumstances are such that either party has been unduly influenced. In another case, the court ruled that water mains laid in city streets are taxable as real property.—*Lewis V. Carpenter.*

The Water Chlorination Equipment of the Schau- und Lehrsammiung der Landesanstalt. J. WILHELMI. Kl. Mitt. Ver. Wasserversorg. Abwässerbeseitig., **3**: 198–202; Chem. Zentr., 1927, II, 1878. From Chem. Abst., **22**: 4682, November 20, 1928. Description with drawings of chlorine disinfecting equipment of the Bomag-Meguin-A.G., chlorination equipment of Dr. ORNSTEIN, and electrolytic plant of ARTHUR STAHL, Aue i. Sa.—*R. E. Thompson.*

The Halogens and Public Water Supplies. JOSEPH S. HEPBURN. Hahnemannian Monthly, **63**: 641–9, 1928; Catalyst, **13**: 7, 21–4; 8, 7, 1928. From Chem. Abst., **22**: 4682, November 20, 1928. Review devoted to iodization, use of chlorine, hypochlorites, chloramines (chlorine plus ammonia) and other chlorine compounds, superchlorination followed by dechlorination, "chlorine taste" and its prevention. Bibliography included.—*R. E. Thompson.*

The Oxygen Content of Water. H. STOOFF. Kl. Mitt. Ver Wasserversorg. Abwässerbesitig., **2**: 13–21, 1926; Chem. Zentr., 1927, II, 1743. From Chem. Abst., **22**: 4683, November 20, 1928. With aid of 3 tables of solubility of air in in water at 1–30°, of oxygen in distilled water at 0–90°, and of oxygen in salt water at 0–30°, the significance of oxygen in natural waters is discussed.—*R. E. Thompson.*

Presence and Detection of Arsenic in Water. H. KLUT. Kl. Mitt. Ver. Wasserversorg. Abwässerbeseitig., **3**: 191–4; Chem. Zentr., 1927, II, 1879. From Chem. Abst., **22**: 4683, November 20, 1928. Following discussion of presence and limits of toxicity (0.2 p.p.m. arsenious acid), detection of arsenic by methods of GUTZEIT and of BECK, MERRES, and SMITH are described.—*R. E. Thompson.*

Navy Specifications for Diesel Oil. H. C. DINGER. Power, **68**: 556–7, 1928. From Chem. Abst., **22**: 4783, November 20, 1928. Principal requirements are: minimum flash point, 150°F.; maximum viscosity, 200 seconds at 32°F.; maximum water and sediment, 0.5 percent; maximum sulfur, 1.5 percent; maximum ash, 0.1 percent.—*R. E. Thompson.*

Lead Poisoning from Lead-Piped Water Supplies. WADE WRIGHT, C. O. SAPPINGTON and ELEANOR RANTOUL. J. Ind. Hyg., **10**: 234–52, 1928. From Chem. Abst., **22**: 4683, November 20, 1928. Of 90 sources including city, well, and spring waters, all contained lead, and 35 of them caused poisoning as determined by hemoglobin tests and making of blood smears. Of 253 exposed persons, 63, or 24.9 percent, were poisoned.—*R. E. Thompson.*

The Allowable Limit of Lead in Drinking Water and Water for Other Uses. HANS BEGER. Kl. Mitt. Ver. Wasserversorg. Abwässerbeseitig., **2**: 171–3, 1926; Chem. Zentr., 1927, II, 1743. From Chem. Abst., **22**: 4683, November 20, 1928. Study of literature shows disagreement over limiting value over which lead in water is toxic, limits varying from 0.025 to 1.0 p.p.m.—*R. E. Thompson.*

The Newly Completed Water Works of the City of Oneida, New York. NICHOLAS KNIGHT. Proc. Iowa Acad. Sci., **34**: 219, 1927. From Chem. Abst., **22**: 4686, November 20, 1928. Supply is obtained from Florence Creek, being conveyed 22 miles through 20-inch main. Watershed contains 17 square miles, very sparsely settled, and danger of contamination is slight. Dam 400 feet long and 50 feet high near Taberg will impound 200 million gallons, equivalent to 3 months' supply. Water is unusually soft and pure.—*R. E. Thompson.*

Scarborough (England) Water Works. HERBERT LAPWORTH. Munic. Eng. Sanit. Record, **81**: 320, 1928. From Chem. Abst., **22**: 4686, November 20, 1928. Supply is obtained from well and borehole 428 feet deep, 3½ miles from service reservoirs. New scheme provides for supply of 2,640,000 gallons per day, additional well and borehole 430 feet deep having been completed. Estimated cost of new scheme is £102,150.—*R. E. Thompson.*

Manganese in Iowa City Waters. EDWARD BARTOW and W. T. BAILEY. Proc. Iowa Acad. Sci., **34**: 191–5, 1927. From Chem. Abst., **22**: 4683, November 20, 1928. Deposit showing quantities of manganese dioxide, as indicated by evolution of chlorine from hydrochloric acid, was found in water pipes from University of Iowa well No. 2 located at laundry. Investigation was conducted to determine whether manganese occurred in any definite strata. Practically all of 50 wells examined in Iowa City and immediate vicinity were found to contain small amounts of manganese. Fact that wells located in glacial drift contain fairly large amount of manganese (0.13–0.25 p.p.m.) and extremely large amount found in infiltration gallery (1.8 p.p.m.) would indicate that manganese occurs largely in glacial and alluvial drifts. Presence of fairly large amounts of manganese in such wells in Iowa City might be explained by fact that limestone is not solid, but contains many large crevices through which soil waters may be carried into wells. Results indicate that manganese may be concentrated in pockets, as is true of iron, and that it would be impossible to predict where a well might be located to secure water free from manganese, except perhaps in deep well in rock. Inasmuch as 5 wells penetrating limestone to depths of from 180 to 400 feet show less than 0.1 p.p.m., it might be possible to prevent manganese-bearing waters from entering such a well by having good junction of casing to shut out waters from drift. Short bibliography appended.—*R. E. Thompson.*

What Effect has the Introduction of Sulfite Waste Liquor Upon the Acidity of River Water? ERIK ÖMAN. Papier-Fabr., **26**: 529–32, 1928. From Chem. Abst., **22**: 4687, November 20, 1928. Values (pH) found were: river water above mill, 6.6; with waste liquor in 1:350 dilution, 4.8; with waste liquor in

1:3000 dilution, 6.4. Buffer capacity of water may have considerable effect. Atmospheric oxidation of sulfite may further decrease pH about 0.2. Highest acidity found is probably without harmful effect upon aquatic life. This does not preclude such effect from other components of waste.—*R. E. Thompson.*

The Carbon Dioxide Tension of the Fraser River and Its Lower Tributaries and of Certain Tributaries of the Columbia River. EDWIN B. POWERS and THESSA A. HICKMAN. Pub. Puget Sound Biol. Sta., **5**: 373–80, 1928. From Chem. Abst., **22**: 4684, November 20, 1928. Lakes and rivers draining lakes had in general a lower carbon dioxide tension, average 0.57, than rivers not fed by lakes, average 1.05 mm. mercury. Typical mountain streams apparently had higher carbon dioxide tension than streams of lower land. **The Carbon Dioxide Tension, Oxygen Content, the pH, and the Alkali Reserve of Natural Waters Mostly of Western Portion of the U. S.** EDWIN B. POWERS. Ibid., 381–91. Waters of lakes and of rivers draining lakes, other things being equal, had lower carbon dioxide tension and higher oxygen content than waters of rivers not fed by lakes. Mountain streams in general had lower pH than streams of lower lands.—*R. E. Thompson.*

Chemical Study of the Waters of Argyle Lagoon. I. PHOEBE BLALOCK and THOMAS G. THOMPSON. Pub. Puget Sound Boil. Sta., **5**: 341–53, 1928. From Chem. Abst., **22**: 4685, November 20, 1928. Data obtained in study of chemical characteristics of the water given. Definite stratification was evident even in these shallow depths. Organic silt at bottom of lagoon contained hydrogen sulfide, although it was not detected in the water. **Chemistry of the Waters of Argyle Lagoon. II.** GEO. H. HITCHINGS, SELDON P. TODD and THOMAS G. THOMPSON. Ibid., 325–32. Additional data.—*R. E. Thompson.*

Waste Liquors from the Dry Distillation of Solid Fuels. I, II, III, and IV. K. THUMM. Kl. Mitt. Ver. Wasserversorg. Abwässerbeseitig., **1**: 141–9, 1925; **2**: 1–9, 109–13, 236–42, 1926; Chem. Zentr., 1927, II, 1744–5. From Chem. Abst., **22**: 4758, November 20, 1928. Very detailed description of liquid decomposition products of dry distillation of solid fuels, with special reference to phenol content. Numerous references are made to the literature.—*R. E. Thompson.*

The Double Fermentation Process with Intermediate Liming (Hildesheimer Process). A Contribution to the Question of the Purification of Waste Liquors from the Sugar Factory. E. NOLTE. Kl. Mitt. Ver. Wasserversorg. Abwässerbeseitig., **3**: 121–33; Chem. Zentr., 1927, II, 1878. From Chem. Abst., **22**: 4687, November 20, 1928. With low water flow the putrefactive fermentation process is preferred. Both processes can be recommended under proper conditions for purification of press and diffusion liquors only, and not for other waste liquors from sugar plant.—*R. E. Thompson.*

Municipal Undertakings at Exmouth (England). SAMUEL HUTTON. Munic. Eng. Sanit. Record, **81**: 332–3, 1928. From Chem. Abst., **22**: 4686, November 20, 1928. Consumption of water varies from 410,000 to 600,000 gallons. Available supply is over 1 million gallons per day.—*R. E. Thompson.*

The Explosive Properties of Solid Hypochlorite. JOSEF WEICHHERZ. Chem.-Ztg., **52**: 729–30, 1928. From Chem. Abst., **22**: 4730, November 20, 1928. Deflagration occurred while transferring calcium hypochlorite from sheet lead containers to small boxes contaminated with alcoholic solution of beech tar soap. Closed, original containers often show as much as 10 per cent internal pressure at 25°, due to oxygen evolution. At 100° to 112°, calcium hypochlorite decomposes rapidly and often violently. When mixed with dry organic substances, there is no reaction at ordinary temperatures, but ignition occurs below 100°. Dry mixtures of hypochlorite with the soap did not ignite, but when moist, there was oxidation, chlorination, and rise of temperature to ignition point. Calcium hypochlorite is not dangerous for disinfection purposes. Deflagration occurs only on strong heating, or when mixed with combustible substances.—*R. E. Thompson.*

Meter and Flow-Control Device for Proportionate Feeding of Chlorine to Water, etc. PAUL LANHAM. U. S. 1,689,491, October 30, 1928. From Chem. Abst., **23**: 227, January 10, 1929.—*R. E. Thompson.*

Improvements of Steam Boiler Plants. PETER. Arch. Wärmewirt., **9**: 157, 1928. From Chem. Abst., **22**: 4759, November 20, 1928. Author proposes to reverse direction of chain grates, so as to bring ashes out front. This would help ignition of coal.—*R. E. Thompson.*

A Study of Flue-Gas Analyses. FRED M. REITER. Gas Age-Record, **62**: 437–8, 452, 1928. From Chem. Abst., **22**: 4772, November 20, 1928. Effect of hydrogen in fuel and excess air on flue gas analyses is discussed. Stoichiometric calculation of flue gas, as means of checking analysis, and possible errors in sampling and analysis also considered.—*R. E. Thompson.*

False Readings of Flue-Gas Testers. FICKERT. Arch. Wärmewirt., **9**: 124, 1928. From Chem. Abst., **22**: 4772, November 20, 1928. In carbon dioxide meters depending on heat conductivity, presence of hydrogen, due to its high conductivity, causes abnormally low carbon dioxide readings. Such meters cannot be relied on unless means of measuring combustibles are also provided.—*R. E. Thompson.*

Hard Water and Rosin-Size Emulsions. C. N. RIDLEY. Paper Makers' Monthly, J., **66**: 415–9, 1928. From Chem. Abst., **22**: 4811, November 20, 1928. Discussion of effect of permanent hardness of water on precipitation of rosin from size emulsions. Rate of separation of rosin from its emulsion increases more rapidly with water containing permanent hardness alone than with water containing both permanent and temporary hardness, which is explained by fact that sodium carbonate set free by action of temporary hardness on sodium resinate reacts with permanent hardness and prevents it from affecting the resinate.—*R. E. Thompson.*

The Corrosion of Iron. W. VANW. SCHOLTEN. Gas- u. Wasserfach, **71**: 872–80, 1928. From Chem. Abst., **23**: 83, January 10, 1929. Comprehensive review of electrolytic theory of corrosion, together with extensive up-to-date bibliography.—*R. E. Thompson.*

Investigation of the Impurities in the Water of the Kiel Inlet. KARL KISSKALT. Arch. Hyg., **99**: 99–110, 1928. From Chem. Abst., **23**: 224, January 10, 1929. Analyses given of water from various parts of Harbor.—*R. E. Thompson.*

Results of the Investigation of the Impurities in the Water of Kiel Inlet in the Years 1926–7. W. LIESE. Arch. Hyg., **99**: 111–7, 1928. From Chem. Abst., **23**: 224, January 10, 1929.—*R. E. Thompson.*

Centrifugal Pumps with Automatic Equipment. N. C. BYE. Iron Steel Eng., **5**: 332–3, 1928. From Chem. Abst., **23**: 1, January 10, 1929. System of remote control of centrifugal pumps with automatic features is described. As level in a water tower falls, a main pressure regulator starts a priming pump which exhausts air from main pump through priming line and vacuum breaker. When water reaches latter it raises a float closing the vacuum breaker switch, starting the main pump motor and shutting down the priming pump motor. With increase in speed, main pump motor develops sufficient pressure to shut off the vacuum breaker, and at full speed the pressure opens the main line check valve. When tower is filled the main pressure regulator opens and shuts down the pump. Simultaneously, the decrease in speed closes main line check valve. Diagrams of plant are included.—*R. E. Thompson.*

Alloy Steel for Boiler Construction. CHARLES MCKNIGHT. Trans. Am. Soc. Steel Treating, **13**: 617–56, 1928. From Chem. Abst., **23**: 80, January 10, 1929. Compilation of recent applications of nickel steel for boilers. Nickel steel offers 25–40 percent increase in strength, toughness, and impact resistance, is immune to aging embrittlement, and more resistant to corrosion. It is suitable for use in boiler tubes and staybolts and can be made to develop higher strengths than are now demanded.—*R. E. Thompson.*

The Chlorine Number and Chlorine Requirement of Water. The Estimation of Ability to Combine with Chlorine. HANS WETTE. Arch. Hyg., **99**: 143–57, 1928. From Chem. Abst., **23**: 225, January 10, 1929. Since some decomposition products of proteins are not oxidized by usual method of KUBEL-TIEMANN, values so determined may fail to show some impurities of hygienic importance. Chlorine number is of value in such cases. Since some chlorine is taken up by organic material and can then no longer exert its bactericidal properties, the amount so removed by combination must apparently be determined in order that just sufficient excess may be present to sterilize the water. When single drop of chlorine water (containing 0.01 milligram chlorine) was added to distilled water, to conductivity water, or to urea solutions of varying concentration, no test for chlorine could be obtained with benzidine after 5 minutes. Second drop of chlorine water gave positive test for all solutions. This test is not sufficient to determine amount of extra chlorine required by the urea in the solution. Sodium bicarbonate unites with chlorine, and amount so taken up is not affected by presence of dissolved urea—*R. E. Thompson.*

British and American Practice in Rapid Sand Filtration. S. W. FARRINGTON. Munic. Sanit. Rec., **81**: 546–7, 1928; cf. C. A., **22**: 4683. From Chem. Abst., **23**: 225, Janjary 10, 1929. Discussion of different practices in automatic control of chemical feeding in accordance with water flow, the times of reaction and flocculation, and washing of filters. In Cork, no quiescent subsidence period is provided. Applied water therefore contains no floc but a finely divided precipitate. Wash water flows over weir at end of filter a few inches above the sand instead of being carried off in troughs. Vertical velocity is therefore at minimum; 6.25 gallons per square foot per minute.—*R. E. Thompson.*

Some Municipal Works at Totnes (England). JOHN L. DAVIES. Munic. Eng. Sanit. Record, **81**: 517, 1928. From Chem. Abst., **23**: 226, January 10, 1929. Brief data on water supply, etc.—*R. E. Thompson.*

Recent Municipal Work in Stafford, England. W. PLANT. Munic. Eng. Sanit. Rec., **81**: 462–3, 1928. From Chem. Abst., **23**: 226, January 10, 1929. Water supply is pumped from well and bore hole. Inadequate storage reservoir of 577,000 gallons will be replaced by million gallon concrete storage reservoir (2-day normal supply).—*R. E. Thompson.*

Experiences with Purification of Sugar Factory Pulp-Press Water by Fermentation. OTTO UNGNADE. Centr. Zuckerind., **35**: 1097–8, 1927. From Chem. Abst., **23**: 297, January 10, 1929. Press water was collected separately and allowed to undergo lactic acid fermentation. This removed all sugar, and apparently modified rest of organic matter somewhat. It was then limed, precipitating not only calcium lactate, but also most of albuminous substances. Result was clear effluent which was mixed with condenser and beet-flume water and sent to settling basins. There are sufficient bacteria in effluent to effect considerable further purification in settling basins. Suspended matter was lowered from 8560 to 2300 milligrams per liter, total nitrogen from 112 to 28, organic nitrogen 88.2 to 15.4, and permanganate consumption from 19,435 to 1140.—*R. E. Thompson.*

Effects of Atmospheric Germs on Household Beverages. (Miss) R. DUFLOS. Chimie et industrie, Special No., 834–41, April, 1928. From Chem. Abst., **23**: 219, January 10, 1929. Brief general discussion of good and bad effects of atmospheric germs on water, etc.—*R. E. Thompson.*

River Pollution. C. C. DUNCAN. Munic. Eng. Sanit. Record, **81**: 501–2, 1928. From Chem. Abst., **23**: 225, January 10, 1929. River Severn is not seriously polluted. The water, after purification, is employed by towns of Worcester and Tewkesbury. Turbidity necessitates frequent cleaning of filters.—*R. E. Thompson.*

An Enquiry into Methods for the Purification and Disposal of Waste Waters. PARK ROSS and L. F. DE FROBERVILLE. Intern. Sugar J., **30**: 376–82, 1928;

cf. C.A., **22**: 2677. From Chem. Abst., **23**: 300, January 10, 1929. Nuisance from waste waters in South Africa has attained serious proportions and investigation of European methods of disposal was decided upon. Standards for effluents discharging into fishing rivers are: (1) not more than 0.3 p.p.m. suspended matter; (2) non-putrescible on incubation for 5 days at 18°; (3); absorption of dissolved or atmospheric oxygen in 5 days not more than 0.15 p.p.m. Waste waters in Natal are principally from two sources: (1) molasses distilleries and (2) sugar factories. Possible methods of disposal of former are application on land, evaporation, and biological purification. Latter seems best adapted to South African conditions. Filtration through biological and sand filters renders waste entirely uninjurious to fish. Of methods considered for treatment of cane factory waste waters, the chemical precipitation method with recovery and reuse of water is the best for conditions in South Africa.—*R. E. Thompson.*

Hamburg Water Supply. Ground Water Supply from Curslack. W. Holthusen. Gas- u. Wasserfach, **71**: 913–24, 1928. From Chem. Abst., **23**: 224, January 10, 1929. Methods of avoiding ground water contamination by seepage into wells and other details of plant are described and illustrated.—*R. E. Thompson.*

Corrosion in Refineries Menaces Profits, Health, and Life; Some Suggestions. E. R. Lederer. Natl. Petroleum News, **20**: No. 40, 22–5, 1928. From Chem. Abst., **23**: 269, January 10, 1929. Palliative measures suggested include (1) proper treatment of boiler feed water and use of proper metal tubes, and (2) analyses of soil and coating of pipes.—*R. E. Thompson.*

Filtering and Washing Process in Open Installations for Removing Iron. G. Thiem. Gas- u. Wasserfach, **71**: 852–4, 1928. From Chem. Abst., **23**: 459, January 20, 1929. Method and theory of washing fine and coarse filters discussed.—*R. E. Thompson.*

The Manufacture of Steel Pipes. Ewald Röber. Stahl u. Eisen, **48**: 1113–20, 1928. From Chem. Abst., **23**: 362, January 20, 1929. Various methods for manufacture of steel pipes described and illustrated with graphs. Smallest and largest diameters obtainable by the various methods are tabulated. Methods are compared and their future discussed.—*R. E. Thompson.*

Rusting and Protection of Iron. M. Schulz-Kirchmöser. Intern. Congress Testing Materials, **2**: 592–602, 1927. From Chem. Abst., **23**: 364, January 20, 1929. Discussion of theories of corrosion and methods of protection. Unpigmented oil films do not prevent corrosion. Red lead is most effective pigment, being superior to red ocher and other substitute pigments. So-called "dispersion red lead" is better than the ordinary product in accelerated tests, in resistance to caking and settling, and in brushing. Caking is less noticeable with pigments containing minimum amount of excess litharge. To prevent lead poisoning, old paint may be removed by wet sand blast.—*R. E. Thompson.*

The Use of Copper Coils in Distilling Apparatus for the Preparation of Distilled Water. H. W. VAN URK. Pharm. Weekblad, **65**: 1075–7, 1928. From Chem. Abst., **23**: 459, January 20, 1929. Unless copper is protected by coating of tin, traces of the metal are likely to be found in the distilled water.—*R. E. Thompson.*

Chlorination of Drinking Water. HAYO BRUNS. Gas u. Wasserfach, **71**: 1057–64, 1928. From Chem. Abst., **23**: 458, January 23, 1929. Development of chlorination reviewed and necessity of careful control pointed out. History of numerous typhoid epidemics given. Correct excess chlorine content is about 0.1 p.p.m. Methods of determining free chlorine are described, including α-naphthoflavone test. Taste due to phenol may be avoided by excess chlorine and subsequent dechlorination. Taste develops more strongly in cold weather.—*R. E. Thompson.*

Chlorine Content as Index of the Potability of Water Supplies. L. GILLET and C. H. GUILLEAUME. Tech. Sanit. Munic., **23**: 177–80, 1928. From Chem. Abst., **23**: 458, January 20, 1929. Fairly definite limits for chloride as indicator of pollution may be established for each region if deductions are made for chloride derived from minerals. Great credence is placed on chloride content as index of potability.—*R. E. Thompson.*

An Apparatus for Adding Gypsum to Irrigation Water. S. C. SCOFIELD and ELMER W. KNIGHT. U. S. Dept. of Agr., Circ. **38**: 1–5, 1928. From Chem. Abst., **23**: 458, January 20, 1929. Description of automatic distributor designed for adding proper amount of gypsum to irrigation ditch.—*R. E. Thompson.*

Diurnal Variation of the Gaseous Constituents of River Waters. III. ROGER WM. BUTCHER, FREDERICK T. K. PENTELOW and JAMES WM. A. WOODLEY. Biochem. J., **22**: 1035–47, 1928, cf. C.A., **22**: 1202. From Chem. Abst., **23**: 458, January 20, 1929. Continuation of experiments from September to December. Main factors governing oxygen content of the River Lark are (1) the quality and type of plant life present, these factors being governed by season of year; and (2) the prevailing actinic conditions.—*R. E. Thompson.*

The Electroösmotic Water-Purification Process of the Siemens-Elektro-Osmose G.m.b.H. KURT ILLIG. Siemens-Z, **8**: 349–58, 1928. From Chem. Abst., **23**: 459, January 20, 1929. A more detailed exposition of process and apparatus described in C.A., **22**: 470. Only magnetite anodes are fully successful. Cathodes may be of almost any metal; iron, zinc, and tin are used. Vulcanized fiber is used for all diaphragms except at anodes in last stages, where chrome gelatin is used. Apparatus is supplied in 4 sizes, with capacities of 2.5–250 liters per hour. Either 110 or 220 volts can be used. Cells are built of rubber-coated steel, with hard-rubber or hard-rubber-coated steel separators. Initial cost is higher than for thermal apparatus, but space required and operating cost are much less. 15–40 kilowatt hours per cubic meter is

the energy consumption, compared with 139 for most efficient distillation equipment. Apparatus is as yet too costly for production of large quantities of pure water for boiler feed, but a comprehensive research program is being undertaken in effort to develop higher-capacity equipment built in more economical manner. At present time yearly production of electroösmotically purified water is about 15 million liters.—*R. E. Thompson.*

The Water Supply of Conception, Argentina, from the Uruguay River. EIGENBRODT. Gas- u. Wasserfach, **71**: 943–6, 1928. From Chem. Abst., **23**: 458, January 20, 1929. Water is purified by coagulation with alum and rapid sand filtration. Some details of the novel filtration scheme and costs of operation are given.—*R. E. Thompson.*

High Ratings—No Erosion in Boiler-Furnace Tests at Carborundum Plant. Power, **68**: 839–41, 1928. From Chem. Abst., **23**: 493, January 20, 1929. Furnace burning pulverized coal and lined with carbofax, a silicon carbide refractory, stood up without erosion with boiler rating of 500 percent and combustion rates as high as 50,000 B.t.u. per cubic foot.—*R. E. Thompson.*

The Action of Permutite in Softening Industrial Waters. I. MUTTI and M. BASINI. Ann. chim. applicata, **18**: 387–94, 1928. From Chem. Abst., **23**: 459, January 20, 1929. When both calcium and magnesium salts are present, sodium permutite reacts to greater extent with magnesium. When magnesium salts alone are present, calcium permutite will react so as to transform completely the magnesium salts, whereas magnesium permutite will only react to partial extent with calcium salts. When calcium and magnesium salts react separately with sodium permutite, then the calcium salt is transformed to greater extent, as would be predicted from its greater molecular weight. Explanation of apparent exception to this rule in case when salts are both present at same time is clear from above considerations, calcium permutite being formed at first almost completely and in turn reacting with the magnesium salts present.—*R. E. Thompson.*

Methods of Making Structures Impermeable, Especially by Means of Waterproofers. LOUIS VIENNOT. Ciment, **33**: 355–9, 389–94, 1928. From Chem. Abst., **23**: 496, January 20, 1929. Although there are a few really good waterproofers, most of them are apt to give variable results and should be used with caution. Problem of waterproofing would be eliminated if cement could be developed free from shrinkage.—*R. E. Thompson.*

The Shrinkage of Cements. J. COCAGNE and Mme. Y. MATRAS. Rev. materiaux construction trav. publics 1928, 321–30; cf. C.A., **22**: 4219. From Chem. Abst., **23**: 495, January 20, 1929. Shrinkage varies with cement, amount of mixing water, amount and nature of aggregate, and amount of mixtures. Angular aggregates are preferred. Calcium chloride increases shrinkage. Concrete should be applied as dry as possible and after setting it should be kept wet for a time.—*R. E. Thompson.*

Principles of Combustion. A. A. POTTER and H. L. SOLBERG. Power, **68**: 765-7, 1928. From Chem. Abst., **23**: 498, January 20, 1929. Discussion of elementary principles involved in combustion calculations.—*R. E. Thompson.*

Analyzing the Products of Combustion. A. A. POTTER and H. L. SOLBERG. Power, **68**: 928, 1928. From Chem. Abst., **23**: 498. January 20, 1929. Practical suggestions for collecting gas samples and for using Orsat apparatus.—*R. E. Thompson.*

The Relation Between Carbon Dioxide and Excess Air. A. A. POTTER and H. L. SOLBERG. Power, **68**: 837-9, 1928. From Chem. Abst., **23**: 498, January 20, 1929. Maximum percentage of carbon dioxide in products of combustion can be calculated by formula:

$$CO_2 = \frac{8.81}{0.421 + ((H - O/8)/(C + 0.375))}$$

symbols H, O, and C representing percentages by weight in fuel. Since maximum carbon dioxide can thus be determined when analysis of fuel is known, actual percentage of carbon dioxide in products of combustion can be used as measure of percentage of excess air for combustion, provided combustion is complete.—*R. E. Thompson.*

Pulverized Fuel at the Calumet Power Station, Chicago. F. H. ROSENCRANTZ. Engineering, **126**: 389-91, 398, 1928. From Chem. Abst., **23**: 498, January 20, 1929. Installation of 2 boilers erected in 1926 to burn powdered coal containing 14.5 percent moisture and 18 percent ash is described. These furnaces were first of bin-and-feeder type, but they are now being changed to unit or direct-fired system. Efficiency is 86.5 percent as contrasted with 78 percent for stoker-fired boilers, partly due to fact that only 20 percent excess air is required compared with 40 percent for former installation. Final temperature of products of combustion is 250°F. Boiler can be started from cold in 30 minutes as against 1-1.5 hours for the stoker-fired boiler. Boiler is designed to supply 200,000 pounds of steam per hour at 375 pounds per square inch and 700°F.—*R. E. Thompson.*

Measurement of Flow by Means of Orifice Meters. L. ZIPPERER. Gas- u. Wasserfach, **71**: 1033-5, 1928. From Chem. Abst., **23**: 556, February 10, 1929. Derivation of formula for flow of liquid through orifices is given, together with charts for orifice size.—*R. E. Thompson.*

Recovery of Waste Heat from Internal Combustion Engines. CONSTANTIN REDZICH. Gas- u. Wasserfach, **71**: 1071-2, 1928. From Chem. Abst., **23**: 499, January 20, 1929. Heat may be recovered from cooling water used in jacket of internal combustions, or waste gases may be circulated through waste heat (fire tube) boilers. In this way 1 kilogram of steam at 2 atmospheres pressure can be secured per kilowatt-hour and this will develop 10 percent additional power in steam turbine. Care should be taken to avoid cooling gases to condensing point, as excessive corrosion results. Power developed can be in-

creased from 22 percent of theory to 32 percent; or, if steam is used in chemical processes, the utilization of heat totals about 70 percent of theoretical.—*R. E. Thompson.*

Temperature of Welding Flames. WEHRMANN. Gas- u. Wasserfach, 71: 950–2, 1928. From Chem. Abst., 23: 500, January 20, 1929. Temperatures determined are shown on drawing of flames. Identical temperatures were obtained for usable part of acetylene and illuminating gas flames, when proper burner was used in each case. On a 0.5-meter weld on 1.5-mm. material the two burners were of equal value. Superiority of oxy-acetylene burner over oxy-gas burner on large work appeared to be due to greater amount of heat supplied, 6670 kilogram-calories compared with 5400. It is important that oxy-gas burners should be constructed so that excess oxygen is not required.—*R. E. Thompson.*

Water Problems in Morocco. EDMOND BOUCHY. L'eau, 21: 121–2, 1928. From Chem. Abst., 23: 656, February 10, 1929. Because of arid nature of Morocco, the sanitary engineering problems are quite different from those in France. Use of large reservoirs and very long pipe lines is necessary. Great progress on water engineering projects now under way is reported.—*R. E. Thompson.*

Zeolite Softening. JAMES FITZGERALD. Textile Colorist, 50: 759–60, 1928. From Chem. Abst., 23: 657, February 10, 1929. General.—*R. E. Thompson.*

Corrosion at Discontinuities in Metallic Protective Coatings. II. Different Methods of Applying a Zinc Coating. ULICK R. EVANS. Metal Industry, 33: 281–3, 300–2, 1928. From Chem. Abst., 23: 588, February 10, 1929. Cf. C. A., 22: 4100. By measuring the potentials of galvanized iron *vs.* pure zinc *vs.* time, thickness and type of zinc coating were determined for sprayed, hot-dipped, sherardized, and electrodeposited zinc. The electrodeposited and sprayed coats were pure zinc, the sherardized coating was zinc-iron alloy and the hot-dipped coating, a mixture of alloy and pure zinc. Sprayed and hot-dipped metals showed cracks on convex side when bent. Electrodeposited coatings indicated presence of cracks at bends upon subsequent immersion in 0.5 N sodium chloride solution. Sherardized coating showed cracks on concave side of bend, indicating brittleness in compression. In most cases rust first developed at bends. Heavy sherardizing showed, upon partial immersion, presence of iron rust in 9 days, lightly sherardized coats, in 4 days while electrodeposited coats showed no attack on the iron for 28 days. In Cambridge water, all but the sherardized metal showed no yellow spots for 51 days, while sherardized coating showed slightly yellow tinges after 3 days and heavy yellow deposit after 28 days. Thickly sherardized metal showed yellow tinges after 51 days. Bent specimens showed rust spots at bends after 40 days.—*R. E. Thompson.*

Deterioration of Concrete by Means of Aggressive Carbonic Acid. KARL BIEHL. Beton Eisen, **27**: 371–3, 1928. From Chem. Abst., **23**: 685, February 10, 1929. Superficial attack of concrete lining of canal was attributed to aggressive carbonic acid. Interior of concrete was found to be in good condition. The pH of water coming in contact with the concrete varied from 5.8 to 7.6.—*R. E. Thompson.*

Study of the Failure of Concrete Under Combined Compressive Stresses. F. E. RICHART, A. BRANDTZAEG, and R. L. BROWN. Univ. Illinois, Bull. **26**: 12, 102 pp. 1928. From Chem. Abst., **23**: 686, February 10, 1929.—*R. E. Thompson.*

Improved Process for Casting (Cast-Iron) Pipe Centrifugally in Green Sand Molds. GIUSEPPE GUERRINI. Foundry, **56**: 832–5, 1928. From Chem. Abst., **23**: 586, February 10, 1929. Description of method developed and used in Italy, and comparison of process with that using permanent molds. Italian process has usual advantages of centrifugal casting, namely, good distribution of graphite and phosphorus in form of fine grains and a pearlitic, instead of ferritic, structure, apart from film on inside which may be removed by more rapid cooling. General characteristics of process and pipe produced are pearlitic matrix and great tensile strength; uniformity in the various thicknesses; less heavy than vertically cast pipe; rapid production; low installation and production costs; rejections reduced to minimum; minimum quantity of slag inside pipe because of use of filtering feed runner.—*R. E. Thompson.*

Studies on the Frequency of Goiter in Finland and Its Relation to the Occurrence of Iodine in the Water. ERIK ADLERCREUTZ.—Acta Med. Scand., **69**: 1–45, 1928. From Chem. Abst., **23**: 638, February 10, 1929. Endemic goiter occurs not only in mountains, but also in low lands. The endemics of low lands are localized in lake regions, or occur on shores of certain waters. It is stated that incidence of goiter shows spontaneous diminution in certain localities where disease has been known for very long time. **II. Etiology of Goiter.** Ibid., 187–222. Pointed out that no new theory advanced to explain etiology of goiter is sufficient to account for facts obtainable in territories different from that where theory has been promulgated. It is maintained that uniform type of endemic goiter does not exist, because goiter is result of multiple factors, and regionally one or another factor predominates. **III. The Presence of Iodine in Various Waters in Finland.** Ibid., 325–91. Iodine deficiency is probably not direct cause for goiter in Finland. Incidence in sections is in inverse ratio to presence of iodine. In certain regions marked by relative richness in iodine, endemic goiter is present and lack of iodine in other regions is not always associated with occurrence of disease.—*R. E. Thompson.*

A Study of the Micro-Iodine Titration. ALEXANDER STURM. Biochem. Z., **200**: 273–9, 1928. From Chem. Abst., **23**: 624, February 10, 1929. FELLENBERG's colorimetric method is only reliable in pure solutions of potassium iodide. For quantities above 1γ, titration is proposed. Principle of method is oxidation of the iodide to iodate with chlorine water, evaporation of excess

reagent, and liberation of iodide by addition of purest potassium iodide, titrating with sodium thiosulfate using starch as indicator. The chlorine must be quantitatively removed; in absence of organic matter this is accomplished when solution is evaporated to one-third. Material analyzed must be incinerated in platinum dish and hydrochloric acid solution of ash must be kept absolutely dust-free. Sharpness of end point is very essential. For amounts below 10γ, the optimum concentration of starch is 0.5 cc. of 1 percent solution to volume of 5–6 cc. Starch solution must be prepared fresh daily by boiling 0.1 gram soluble starch in 10 cc. water for 1 minute and keeping at 6–8°, at which temperature titration must be carried out. For quantities less than 3γ, the change of indicator is inhibited, but delay is graphically definable. With special care as to preparation of reagent, etc., good results are obtained even with quantities of only 1γ (3 percent error).—*R. E. Thompson.*

Flue Ashes Eliminator. MAX BERGER. Apparatebau **4**: 270–1, 1928. From Chem. Abst., **23**: 734, February 20, 1929. "Deuca-Räumer" is made of special heat-resisting alloy and of such shape that when placed in flue it gives the gases an increased velocity and spiral motion, thus preventing deposition of ashes in flue and giving higher heat utilization.—*R. E. Thompson.*

Apparatus for the Production and Mixing of Solutions by Electrical Control. F. PETZOLD. Chem. Fabrik, 1928; 668–9. From Chem. Abst., **23**: 735, February 20, 1929. Automatic control for process involving mixture of two fluids in predetermined amounts is described.—*R. E. Thompson.*

Progress Report on Cannery Waste Treatment Studies Conducted by the Ohio Canners' Association at Canal Winchester, Ohio, August 24 to October 8, 1926, and Association of New York State Canners, Inc., at Albion, N. Y., August 9 to October 25, 1927. Under supervision of A. ELLIOTT KIMBERLEY. Ohio State Dept. of Health. 85 pp. Cf. C.A., **22**: 656. From Chem. Abst., **23**: 659, February 10, 1929. Illustrated report with diagrams describing test treatments given wastes from canning. Numerous tables show operating data, results of screening and chemical precipitation tests, and composition of screened raw wastes and their effluents.—*R. E. Thompson.*

Neutralizing the Alkalinity of Water. ALFRED H. WHITE. U. S. 1,693,065, November 27. From Chem. Abst., **23**: 660, February 10, 1929. In order to render alkaline water suitable for use in boilers it is treated with sufficient phosphoric acid to adjust final acidity after reaction and removal of its carbon dioxide content, to proportion not in excess of 0.5 percent. U. S. 1,693,066 specifies preparing water for use in boilers by adding sufficient phosphoric acid to form insoluble phosphates with calcium, magnesium and iron carbonates in solution and sufficient sodium phosphate to form insoluble phosphates with other calcium, magnesium, and iron salts in solution, additions being made in such proportions as to effect substantial neutralization of water after carbon dioxide has been removed from solution.—*R. E. Thompson.*

Protecting Iron Water Pipes. CHRISTIAN BÜCHER. Swiss 126,205, October 4, 1926. From Chem. Abst., 23: 660, February 10, 1929. Iron pipes are preserved from attack by treating water with sufficient lime to unite with all carbon dioxide and to render water neutral or alkaline.—*R. E. Thompson.*

Watch the Outside Surface of Your Boiler. I. S. CHAMBERLAIN. Power, 68: 998–9, 1928. From Chem. Abst., 23: 806, February 20, 1929. External corrosion of boilers is often overlooked.—*R. E. Thompson.*

Quantitative Separation of Alkali Metals from Calcium and Magnesium by Means of Amyl Alcohol. D. KÖSZEGI. Acta Sci. Regiae Univ. Hung. Francisco Iosephinae, II: 214–25, 1927. From Chem. Abst., 23: 791, February 20, 1929. GOOCH stated that amyl alcohol has a very small solvent effect on sodium and potassium chlorides. Amyl alcohol therefore may be used for separating calcium and magnesium chlorides from those of sodium and potassium, as anhydrous hot amyl alcohol dissolves the chlorides of calcium, magnesium, and lithium.—*R. E. Thompson.*

Use of Methyl Orange for the Detection of Free Chlorine and Chloramines. BESEMANN. Chem.-Ztg., 52: 826, 1928. From Chem. Abst., 23: 792, February 20, 1929. Methyl orange is sensitive to chloramine, or hypochlorite, only in acid solution. Thus if dilute chlorine water is made alkaline with sodium hydroxide and then methyl orange added, the indicator retains its yellow color. On making acid, the methyl orange is bleached. Similarly by adding ammonium hydroxide or an amine to chlorine, the bleaching effect of chlorine is lost; but now on making solution acid there is no bleaching effect although other reagents for chlorine are affected. Conclusion: Methyl orange serves to differentiate between free chlorine and chloramines. This probably explains Grassberger's tests for "apparently free" and "actually free" chlorine in drinking water. [Cf this JOURNAL, 21: 4, 586–8, April, 1929].—*R. E. Thompson.*

Goiter and Water Supply. WAGNER-JAUREGG. Gas- u. Wasserfach, 71: 817–21, 1928. From Chem. Abst., 23: 897, February 20, 1929. Literature is reviewed and shown to be somewhat conflicting. Author's experiments with rats indicate that other factors than drinking water are more important, as rats in regions where goiter prevailed developed goiter even when given drinking water from goiter-free regions and vice versa. Possible influence of bacteria or other organic impurities in causing goiter make it desirable to secure purest water supply, free even from bacteria considered to be non-pathogenic. —*R. E. Thompson.*

Flow Constants of IG-Orifices for Water, Oil, Steam, and Gas. R. WITTE. Z. Ver. deut. Ing., 72: 1493–1502, 1928. From Chem. Abst., 23: 918, February 20, 1929. Summary of some 18 years' experience in measuring flow of liquids and gases at Oppau and Leuna works. Present differences obtained with carefully constructed orifices of several types are used as basis of calculations. New calibrations were undertaken because variations of 1 to 3 percent in

results had been obtained by using the older values, and pipe sizes had changed so much since older constants were measured. Results reported for (1) water in pipes of 50 to 500 millimeters diameter; (2) steam in pipes of 50 to 500 millimeters diameter and under pressure of 4 to 40 atmospheres at same or higher REYNOLDS numbers (REYNOLDS number, R = pipe diameter × velocity ÷ kinematic viscosity); (3) air in region of smaller REYNOLDS numbers than for water. Accuracy of ± 0.5 percent is attainable, if due attention is given to pipe diameter and form of orifice. For one and the same throttling diaphragm and for different media the mechanics are the same; but this is not the case if pipe diameter is changed. From the experimentally determined constants and their curves as given, values can be found for computing flow of gases and liquids in pipes of from 50 to 500 millimeters diameter.—*R. E. Thompson.*

Potable Water Purification in North America with Special Reference to Chlorination. ORNSTEIN. Gas- u. Wasserfach, 71: 1081–3, 1928. From Chem. Abst., 23: 922, February 20, 1929. Review of necessity for chlorination and of methods used. Possibility of destroying excess chlorine with sulfur dioxide is noted. Author notes that he installed first chlorination equipment at Niagara in 1912. Since that time no corrosion phenomena due to chlorination have been noted. Chlorination apparatus itself has had no repairs outside of replacement of low-pressure manometer.—*R. E. Thompson.*

Iron in Paper Mill Water. FRED GROVE-PALMER. Paper Maker & Brit. Paper Trade J., 76: 491–2, 1928. From Chem. Abst., 23: 975, February 20, 1929. Brief discussion of methods of eliminating iron.—*R. E. Thompson.*

Tests of the Remscheid System for Protecting Pipe. THIESING and L. W. HAASE. Gas- u. Wasserfach, 71: 961–4, 988–95, 1928. From Chem. Abst., 23: 922, February 20, 1929. Very complete tests were made of BÜCHER system for protecting iron pipes from corrosion by water containing excessive amounts of carbon dioxide. Sufficient lime was added to convert all carbon dioxide and bicarbonate to carbonate. In presence of oxygen a protective layer was quickly formed. After the initial period, during which an excess of lime was used, the hardness of the water was increased only 5 p.p.m. (CaO). Such coatings are formed on cast iron, zinc, or lead; but on steel the protective coating is only formed in electronegative places. The iron content of the treated water from various parts of system averaged less than that of the untreated water and the taste, odor, and color were satisfactory.—*R. E. Thompson.*

Significance of the B. Coli Test for Ground Water and Other Sources of Potable Water. M. NEISSER. Gas- u. Wasserfach, 71: 1105–7, 1928: cf. C.A., 22: 470. From Chem. Abst., 23: 922, February 20, 1929. Discussion of significance of usual tests for *B. coli* depending on indole formation. Test is of value for the individual source, provided that inspections of source are made at least twice every week. It may give valuable warning, but should not be relied on to too great an extent. Danger of contamination by men repairing mains pointed out.—*R. E. Thompson.*

The Determination of the Bacterial Count of Water. W. PLUCKER and W. BARTELS. Z. Untersuch. Lebensm., 55: 41–60, 1928. From Chem. Abst., 23: 922, February 20, 1929. Medium consisting of 5 percent gelatin and 0.75 percent agar gave results fully equal to those obtained with nutrient gelatin. Highest counts were obtained when medium was adjusted to pH 7.

Treating Water with Chlorine. J. MUCHKA. Brit. 290,166, May 7, 1927. From Chem. Abst., 23: 924, February 20, 1929. Free chlorine is separated from chlorinated water by passing it through carbon or carbonaceous material. —*R. E. Thompson.*

Dissolved-Oxygen Absorption Test. III. E. A. COOPER and S. D. NICHOLAS. J. Soc. Chem. Ind., 47: 320-2T, 1928; cf. C.A., 21: 2520; 22: 472. From Chem. Abst., 23: 923, February 20, 1929. Additional experiments confirm the accelerating effect of sodium permolybdate solutions on rate of dissolved oxygen absorption by sewage effluents. Increased oxygen absorption is due to stimulated bacterial activity and to direct chemical oxidation induced by the permolybdate. The active substance has not yet been isolated. Permolybdate made from molybdic acid is most reliable.—*R. E. Thompson.*

Sanitary Analysis in the Pulp and Paper Industry. L. F. WARWICK. Paper Trade J., 87: 20, 42–4, 1928. From Chem. Abst., 23: 975, February 20, 1929. Outline of methods of chemical examination found satisfactory in investigation of effect of pulp and paper mill wastes on streams. The methods are suggested for adoption as tentative standards for such investigations. Detailed description of method for determining oxygen demand of wastes included.—*R. E. Thompson.*

Report on Waste Utilization. C. M. BAKER. Paper Mill, 51: 51, 22, 26, 1928. From Chem. Abst., 23: 975, February 20, 1929. Summary of first year's activities of National Committee on Waste Utilization and Stream Improvement.—*R. E. Thompson.*

Chemical Analysis of Liquids. United Water Softeners Limited and HENRY STAFFORD HATFIELD. Fr. 641,572, September 20, 1927. From Chem. Abst., 23: 1024, March 10, 1929. Apparatus described for indicating percentage of constituent in liquid, any alteration in electrical conductivity due to chemical change, dissociation, or elimination of constituent being recorded automatically. Application to measurement of temporary hardness of water described. —*R. E. Thompson.*

Corrosion and Metal Protection in Boiler Operation. R. STUMPER. Korrosion u. Metallschutz, 4: 217–27, 1928. From Chem. Abst., 23: 1097, March 10, 1929. Problem of boiler corrosion is subdivided into (1) scaling and burning of grates, tubes, and superheaters; (2) attack of metals by steam; (3) attack of condenser systems; and (4) corrosion of wetted boiler parts. Scaling and burning are influenced by structure of metal, composition of combustible, and purity of boiler water. Porous, graphitic irons are easily oxidized, oxida-

tion starting at the graphitic particles. Sulfur in coal accelerates oxidation by forming iron sulfide, which loosens structure and fluxes the oxides. Impure water causes scale formation inside pipes, local overheating, and burning out. Steam causes oxidation with formation of hydrogen. Introduction of hydrogen into boiler is possible preventative, but too expensive. Corrosion of wetted boiler parts is discussed in light of electrochemical theory. Driving force of reaction is difference in hydrogen and iron potentials, which is shown to have only a small temperature coefficient. Pressure and temperature have opposite tendencies on oxygen solubility and hence on corrosion. Chlorides, sulfates, and nitrates of sodium, calcium, and magnesium increase corrosion of boiler waters; 0.2 percent sodium hydroxide minimizes boiler corrosion. Too high alkalinity tends to cause hydrogen embrittlement; this can, however, be remedied by presence of sulfates.—*R. E. Thompson.*

Regarding the Colloidal Theory of Corrosion. GERHARD SCHIKORR. Korrosion u. Metallschutz, **4**: 242–5, 1928. From Chem. Abst., **23**: 1096, March 10, 1929. A discussion to show that J. A. N. FRIEND'S colloidal theory of corrosion (C.A., **18**: 1461) is incorrect.—*R. E. Thompson.*

Prevention of Corrosion Under Water. R. A. BOYD. Refiner Natural Gasoline Mfr., **7**: 7, 78, 92, 1928. From Chem. Abst., **23**: 1097, March 10, 1929. Methods for preventing corrosion under water reviewed briefly.—*R. E. Thompson.*

Plant for De-acidification. FRIEDEL. Städt. Tiefbau, 1928, 76; Wass. u. Abwass., 1928, **24**: 271. The process of de-acidification consists in aëration by means of spraying and filtering through a marble filter. The filter, consisting of a lower layer of large grains, and an upper layer of fine marble grains, is 1.50 metres in height. The rate of filtration is 1.25 metres per hour; so that one square metre of the filter surface de-acidifies 30 cubic metres of water a day. The de-acidification reduces the free carbonic acid from 48 to 5 mg. per litre and increases the total hardness from 1.8 to 5.20.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

Works Experience in the Chemical Supervision of Rapid Filtration Plant. F. EGGER. Vom Wasser; Verein deutscher Chemiker, Berlin, 1927, **1**: 53. A description of observations made on the purification of the regular water supply of Stuttgart from the Neckar, a hard water, slightly polluted with domestic and industrial effluents, and of the water from a reservoir above Stuttgart, a softer, and purer water. Experiments were also made with aëration for the improvement of the taste, and with the use of screens and slow filtration as a more economical method than rapid filtration but no satisfactory results were achieved. In the course of discussion HAUPT pointed out that in America for slow filtration the time allowed for settling was as long as 6 hours—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

Water Plants as Indicators. H. GANS. Fischerer Ztg., 1925, **28**: 914. Wass. u. Abwass., 1928, **24**: 83. The author gives two classifications of water plants, one according to their distribution and the other according to the shape of their leaves. As the result of many experiments and observations, he has come to the conclusion that the plants show a close relationship to the conditions under which they live, and that they could be used as indicators of the properties of the water in which they are growing. He describes a number of plants, noting their requirements in relation to water level, temperature, light, oxygen content, acidity and alkalinity, iron and sulphur compounds, etc. Much experimental work is necessary, however, before these plants can be used with any certainty to judge the character of water.—*M. H. Coblentz* (*Courtesty of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

Water Distillation Plant: an Improved Multi-Stage Process. Chem. Trade J. and Chem. Eng., 1929, **84**: 2193, 523. The use of distilled water would be greatly extended if it could be produced at a reasonable expenditure of fuel. The practise of evaporating the water and condensing the steam to water is uneconomic, as most of the heat is lost with the cooling water. To avoid this, the "Christ" multi-stage water still utilizes the partly spent steam to produce a similar quantity of steam and repeats the process several times. A graduation of temperature and pressure is provided to ensure that the heating steam is of higher temperature and pressure than the new steam to be produced. The evaporators are built in a column. The first evaporator absorbs some of the heat and pressure of the steam and produces some distilled water; the partly spent steam enters the second compartment, losing further heat and producing more distilled water and so on in each evaporator compartment. The complete exhaustion of heat produces great fuel economy and there is also economy in cooling water as only the steam of the last compartment has to be condensed therewith. The apparatus can be constructed in different sizes for furnace or steam heating. The heating surfaces are easily removable for cleaning. The system is put on the market by C. F. S. Giesler, Ltd., Swinton House, London, W. C. 1.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

The Lytic Phenomenon of d'Herelle in Relation to the Bacterial Flora of Sea Water. L. FORTUNATO. Zbl. ges. Hyg., 1928, **18**: 775; Wass. u. Abwass., 1929, **25**: 259. The author tested the water from the harbour and the straits of Messina for the presence of a lytic agent and, if so, to discover if there is any relation between the bacterial flora and this agent. Samples of water at various distances from the mouth of the sewer were taken and their effect on typhoid, paratyphoid A and B, Shiga, and coli bacteria was tested. The presence of a lytic agent, independent of atmospheric and meteorological changes, was detected in every case. It is subject to individual alterations; is always present with *B. coli* and Shiga, but never with paratyphoid. The degree of the lysis increases with decreasing numbers of bacteria. These determinations show that the activity of bacteriophage must be considered in account-

ing for the self-purification of water.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

The Softening of Feed Water for Locomotives in the United States. H. HAUPT. Vom. Wasser., Ver. deutscher Chemiker. Berlin, 1928, 2: 162. HAUPT gives a short account of four papers given before the American Chemical Society by L. O. GUNDERSON, G. L. BAXTER, H. H. RICHARDSON, and C. S. JOHNSON and summarizes as follows the more important conclusions: the modern softening of boiler feed waters prevents boiler scale formation and thus lengthens the period of use of the engine: the permutit process appears to have the best effect: water should be sufficiently alkaline to give security against corrosion and should be as free as possible from oxygen: the concentration of the boiler contents must be controlled and blowing off must be fairly frequent to prevent foaming and priming: the construction must be suitable for this. *M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

New Methods of Sterilization. R. DEGKWITZ. Klinische Wochenschrift, 1929, 8: 343. Gesund. Ing., 1929, 52: 20, 366. The author confirms the earlier results of KRAUSE on complete bacteriological filtration. He describes a test lasting for three months when water was passed through a filter of quartz sand with 10 percent of silver. The filter consisted of three thin layers and was not in itself impervious to bacteria. With the silver addition, only when the flow was very rapid did bacteria appear in the filtrate and these died in 15 to 20 minutes. Bacteria introduced into the filtered water died in 2 to 3 hours. After the filtration, the sand layers were free from bacteria in 15 to 20 minutes. Thus the bacteria held back by the sand are killed by contact with the silver and the water is so activated that it has a destructive effect even on fresh inoculation. Filters of the Berkefeld type, charged with silver, have remained impermeable for months under daily tests.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

Contribution to the Study of the Sterilizing Action on Bacteria Suspended in Water of Small Doses of Chlorine Introduced with Violent Agitation and of Metallic Powders. E. TECHOUYÈRES. Rev. d'Hygiène, 1929, 51: 393. After discussing the importance of chlorination in sterilizing the drinking supplies of towns and villages, the author describes his experiments on new methods of sterilization, under two headings. (1) Experiments on chlorination with very small doses of sodium hypochlorite using the auto-chlorinator devised by PHILIPPE BUNAU-VARILLA during the war. Tests were made on water from the underground supply of Rheims and from the River Marne. (2) Experiments on sterilization with metallic powders. He then discusses the mechanism of the sterilizing action of these suspensions, attributing it to the so-called oligodynamic action of colloidal particles, and brings forward two hypotheses to explain the method of destruction of the bacteria.—*M. H. Coblentz* (*Cour-*

tesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).

Sterilization Experiments with Chloramine Solutions Containing Soda. K. MARCUSE. Z. f. Desinfekt. u. Gesundheitswesen, 1928, **20**: 193. Wass. u. Abwass., 1929, **25**: 307. According to the author's experiments, the sterilizing power of chloramine when dissolved in tap water is greater than when dissolved in 5 percent soda solution in the same proportions, even although satisfactory results can also be obtained with the soda by using higher concentrations and longer contact periods. Hence tap water chloramine is safer and therefore preferable to soda-chloramine. The production of smells and tastes may outweigh any advantage gained from a stronger or more reliable sterilisation. In two series of experiments with tuberculosis bacilli, no difference was found between the sterilising power of the tap water and soda chloramine—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial research, Water Pollution Research Board, Summary of Current Literature*).

New Methods for Preventing Algae Formation in Public Baths. D. SPANNUTH. Gesund. Ing., 1929, **52**: 18, 329. Experiments made by OLSZEWSKI in Dresden, where the growths first appear in channels round the baths, showed that scouring the channels, adding Caporit (calcium hypochlorite), and washing out with formalin were without effect. The best results were got by adding copper sulphate and scouring the channels at intervals with copper sulphate solution. In treating the swimming bath water, chlorine, mono-chloramine, and copper sulphate all required to be added in such quantities that the water was made unpleasant to use. Experiments were then made to get rid of the algae nourishing materials, namely the calcium and magnesium salts, by replacing them with sodium salts. The permutit process was too expensive except in cases where it was also necessary to soften the water. A patent process known as "Algin," however, proved very satisfactory in preventing algae formation. Though the destruction of bacteria was not assured by this process, the necessary addition of chlorine for this purpose was much diminished. Experiments in combining bactericidal with algae-inhibiting substances are in progress.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

Lake Zürich as a Source of Drinking Water and the Maintenance of its Purity. Address by VON GONZENBACH. Gesund. Ing., 1929, **52**: 20, 366. Zürich draws more than half its water from Lake Zürich and much has been said about the pollution of the lake by oil, factory effluents, and sewage. The Institute of Hygiene therefore instituted an examination of the kind and degree of pollution and its influence on the potability of the water. The examination included investigation of the biological condition of the shores and their neighborhood and of the water and mud in various places and at various depths; temperature measurements; calculation of the plankton; bacteriological and chemical analysis. The water from the intake for Zürich to the bathing establishment at Bendlikon was found to be normal in germ-count; but 200 metres

from the outlet of the Bendlikon sewage works, a content of 40,000 bacteria and from 10 to 100 coli per cc. of water was found, and the transparency was much reduced. The ammonia content, both free and albuminoid was also higher. No poisonous waste waters enter the lake. The effective distance of introduced impurities varies with the force of the waves, the weather, and the constituents of the polluting matter; the self-purifying power increases with the content of oxygen. The result of the examintaion is to show that there is no question of danger in the present Zürich water intake, but that the increasing population along the shores is effecting an increase in the sewage burden and that a survey of the connection between water supply and sewage disposal for the whole lake is necessary. During discussion the formation of a society with its headquarters at the Zürich Technical School, to deal with the condition of drinking water throughout Switzerland, was mentioned.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

The Supply of Drinking Water in the Dutch East Indies. J. SMIT. Vom Wasser, Ver. deutscher Chemiker, Berlin, 1927, 1: 44. The problem of water supplies in the Indies has been dealt with only for the great cities; the scattered population, European and native, draw their supplies from separate house wells. The Chinese, Arabs, and natives pay little attention to hygiene and diseases like typhoid and dysentery are endemic. A definite improvement is found in those plantations where the workers are forbidden to drink untreated water, for which weak tea has been substituted. Water problems in the tropics require more investigation. The most important problem is the water supply for country places; chlorination is here impossible, for the method must be cheap and simple enough to be applied by natives without risk. An advance has been made by the application of caustic lime before filtration.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

On the Present Condition of the Hamburg Water Supply. G. NACHTIGALL. Tech. Gemeindebl. 1929, 32: 8, 104. In 1928 a great step was taken towards cutting off the Elbe water from the Hamburg water supply by the opening of the system of wells at Curslack. From 1882 to 1905, when the ground water works at Billbrook were opened to supply 20 per cent of the requirements, the Elbe was the only source of Hamburg water. The Elbe now supplies only 25 per cent or less, the remainder of the 80 per cent coming from the new Curslack ground water supply. The decision to make Hamburg independent of Elbe water was taken on the grounds of the well-known disadvantages of a surface water supply, temperature variation and tastes and smells which appear intermittently. It is hoped that the ground water supply may be still further extended, for at the peak hours in times of great consumption it will still be necessary to add filtered Elbe water, thus causing variations in temperature, hardness, and salinity. The automatically controlled means by which, when the Elbe water is at its best, the mixing is effected, will require readjustment at times in order to supply for industrial use a water varying as little as possible in chemical composition.—*M. H. Coblentz (Courtesy of the Department of*

Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).

Separate Services for Drinking Water and Water for Other Purposes in German Cities. A. HOLZAPFEL. Tech. Gemeindebl., 1929, 32: 8, 116. In the great cities the water for industrial and public use amounts to about four-fifths of the total and this has led to the idea that separate supplies might be advisable. A questionnaire was therefore addressed to those towns which are, or once were, served by a double supply. The advantages of the separate system are said to be as follows: the quantity of highly-priced drinking water to be supplied is reduced to a minimum; this needs only a low-pressure service, as the question of fire need not concern it; the supply for other requirements can be cheap, as it can be taken in nearer the town and needs no preparation. The disadvantages are: the plant with a double conduit system will be more expensive; double operations are necessary which, because of the smallness of their details, cannot be so efficient; the streets are still more laden with mains; in the arranging of connections, exchanges are not impossible; in emergencies, a mixing of using and drinking water is to be feared. Information was obtained from ten German cities: (1) Oldenburg, Pforzheim, and Wiesbaden, which have had separate systems and have given them up. (2) Gera, Frankfurt a. M., Hannover, Stuttgart, Staszfurt, Worms, and Freiberg i. Sa., which still have separate systems. The points on which information was obtained were (1) the reason for the erection of separate systems; (2) are the separate systems old or new? of what kind are post-war systems? (3) the relation of installation costs to those of a single system; (4) the relation of running costs to those of a single system; (5) other economic questions; (6) are hygienic dangers known to have occurred through misuse of using water as drinking water? (7) the method and price of delivery; (8) are the experiences of other cities with separate plants familiar to you? The information received from the different cities is given fully, as the author found that only one of the cities was aware of the existence of separate systems in other cities. The following are the conclusions arrived at by a consideration of the replies received. (1) With the exception of Freiberg i. Sa., which appears to be the only German city satisfied with the separate system, and Gera, which gets a higher price for its softer using water than for its drinking water, the separate water supply has been forced on cities by circumstances and in all cases they aim at the goal which some have reached, namely, the meeting of all needs by a single supply. (2) It is clear that the costs of the double conduit system, of the installations, of the complicated running of two water works, to which is added the ever-present danger of infection, exceed the costs of preparation and purification in a single system.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

The Arrangement and Ventilation of the New Water Intake of the Town of Zittau in Oybintal. G. THIEM. Tech. Gemeindebl., 1929, 32: 8, 110. Before the war a plant for the intake of ground water had already been erected at Teufelsmühle which supplied 25 litres a second. Investigations and borings in the Schulwiese, which is a valley of sandstone rocks belonging to the chalk-

formation, showed that this could be brought up to the required 90 litres and that more could be supplied if necessary. The two most promising borings made could be counted on for 64 litres a second, but five or six borings could be used, and greater depth obtained in the sinking. The syphon conduit for the new supply had to be steeply inclined. The speed of flow at which the water would carry down with it all the air it contained and also the air which leaked into the conduit had to be avoided and it was found that, at the least inclination of the conduit, with a diameter of 300 mm. and a water flow of 65 litres a second, the rise of all air to the highest point of the conduit was ensured. The maintenance of the required pressure was ensured by a series of valves in the floor of the conduit. These arrangements have been made to allow for an increase in quantity up to 105 litres a second. The objection to saw-shaped or step-like conduits is the expense of laying them in a district where at only 1 metre below the surface a hard layer of sandstone with a quartz-hard binding material is found. To trust to the speed of the water to carry off the air is also impossible when the flow, as in this case, varies in quantity. A full description is given of the method by which the water is collected and drawn off and also of the air-tower, which is situated at the highest point of the syphon conduit to deal with the air which has been brought in by the water or has leaked into the conduit. The power for the air pump is got from ground water from Elfenwiese which lies only 400 metres from the Schulwiese but has a water-head 37.4 metres higher. This plant has now been more than a year in use and no diminution in the supply, or breakdown of the somewhat complicated hydraulic and pneumatic system, has been experienced.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

NEW BOOKS

A Survey of the Paris Water Supply. M. F. DIÈNERT. **Annales des Services Techniques d'Hygiène.** Gauthier-Villars et Cie. Paris 1928. Le Service de Surveillance des Eaux d'Alimentation made a detailed survey of the whole system of the Paris water supply during the years 1925, 1926, and 1927 and the results of their investigation are published in a special report. The supply is composed of both underground and surface water. The survey included the inspection of all sources of raw water and the works constructed for collecting, conveying, and purifying the supply. Field surveys were made of the catchment areas, and the wells, bore-holes, aqueducts, etc., were examined. Periodic analyses were made of the water at many points in the supply system. The first part of the report deals with the five sources of underground water from the valleys of the Dhuys, the Avre, the Ioing and the Lunain, the Vanne, and the district of Provins. For each area, the rainfall, amount of flow from springs and wells, and the general properties of the water, such as turbidity, electrical resistance, bacterial content, are noted. The cases of typhoid fever occurring during the three years amongst the population on the drainage area are mentioned. The second part of the report gives statistics of the quantity and describes the methods of treatment of the water from the Seine and the Marne, at the purification works at Ivry and St. Maur. The third

part of the report gives a short survey of the water supplied by small private companies to several of the Paris suburbs and to the parishes in the Department of the Seine. Tables are appended, giving the results of the analyses of many samples of both the raw and treated water from the various sources of the Paris supply, made periodically throughout 1925, 1926, and 1927.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

Atlantic Coastal Plain. Surface Water Supply of United States, 1925. Pt. 2, South Atlantic Slope and Eastern Gulf of Mexico Basins. NATHAN C. GROVER, A. H. HORTON, E. D. BURCHARD, and W. R. KING. 1929. U. S. Geological Survey Water Supply Paper 602.—*Arthur P. Miller.*

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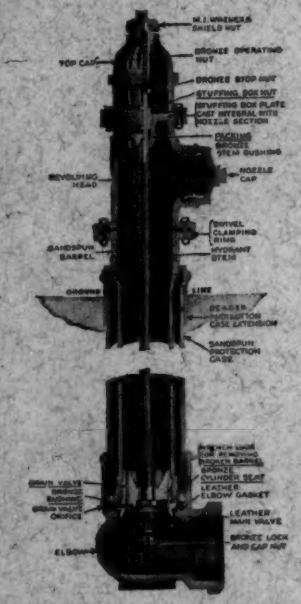

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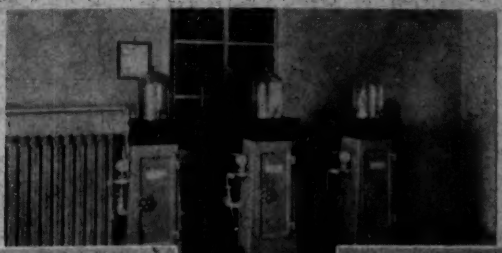

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